A HAND BOOK

OF

General Instruction

FOR

MECHANICS

CONTAINING
USEFUL RULES AND MEMORANDA
FOR PRACTICAL MEN

BY

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NEW YORK
D. VAN NOSTRAND COMPANY
23 MURRAY AND 27 WARREN STS.
1907

The Plimpton Press Norwood Mass. U.S.A.

PREFACE

The primary object of the author in writing this book is to give the mechanic, who has not had educational advantages, a text-book explaining established rules for calculating in a clear, simple, and concise way, making him familiar with the various technical terms and their meaning, and to be in general such a course of instruction as to impart, in a simple manner, the required knowledge to enable him to read understandingly more advanced scientific works.

In writing the book, no attempt has been made to limit the language to the rigid brevity of the average text-book on mathematics and physics, a very free style being used which will be more acceptable to the general reader.

Franklin E. Smith.

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PART I

ARITHMETIC

ARITHMETIC

Arithmetic is the science of numbers and has been known to man in various forms for all time. It is sometimes called the "science of calculation," and when so termed the early period of the science is referred to when (*calculi*) pebbles were used by the savages to make the process of counting, computing, and estimating easy. In Arithmetic there are ten characters called figures:

	1	2	3	4	5	6	7	8	9	0
Named:	one	two	three	four	five	six	seven	eight	nine	nought

And each figure, with the exception of 0, represents a specific collection of single things called units.

By unit is meant a single thing, as one cent, one dollar, one ounce, one pound, etc.

Figure 1 represents one unit.

Figure 2 represents a collection of two units.

Figure 3 represents a collection of three units.

The figure 0 stands for nothing, and when alone expresses no units.

A unit or collection of units is called a number, and a figure is a character used to represent a number; that is, figure 1 may be termed number 1, and figure 9 may be termed number 9.

A number, then, is a unit or a collection of units

Number 1 is called a unit. Number 9 is a collection of nine units. Number 2 is a collection of two units. Number 3 is a collection of three units, etc.

By means of the figures 1, 2, 3, 4, etc., any known number may be represented.

There are also six rules according to which arithmetical operations are performed, called

Numeration.
Notation.
Addition.
Subtraction.
Multiplication.
Division.

The last four of these rules are called the *fundamental rules of Arithmetic,* and upon them depend the solution of all arithmetical problems.

NUMERATION

Numeration is the art of reading numbers which are written in figures. The art of naming the value of figures.

EXAMPLE. Naming the value of 9376267, for instance.

Figures have two values called Simple value and Place value.

The simple value of a figure is the value it has when standing alone, or on the right hand of a number of figures.

In both cases the figure denotes the number of units it represents.

For example, 2 standing alone, or when standing on the right hand of a number of figures, thus, 342, denotes in both two units or ones.

The place value of a figure is the value it denotes when standing with other figures. And the place value of a figure depends upon its relative position to another figure.

For example, each figure of the following number, 1364, has a place value. And that value depends upon the number of places it is toward the left hand from the right-hand figure 4.

Each removal of one place to the left increases the value of a figure ten times.

For example, 4 standing at the left hand of 4, thus, 44, expresses ten times the value it does when standing alone, or in the right-hand place.

Standing alone or on the right-hand place it denotes four units only, but being removed one place to the left, as above, increases its value ten times, and it then denotes ten times four, which is forty, and the four on the right of it denotes four units. And the two figures then together express forty-four (forty-four units or ones).

Again, by removing the figure 4 one place more to the left, making it then three places from the right thus, 444, its value is again increased tenfold.

The first removal to the left increases it from 4 to 40, and the next or third removal increases its value ten times more, making four hundred, and the three figures together express four hundred forty-four.

Each place has a name, as follows, reading from right to left:

Hundreds of Billions.	Tens of Billions.	Billions.	Hundreds of Millions.	Tens of Millions.	Millions.	Hundreds of Thousands.	Tens of Thousands.	Thousands.	Hundreds.	Tens.	Units.
0	0	0,	0	0	0,	0	0	0,	0	0	0,

Often the places occupied by figures are called orders, thus, the right-hand or unit figure is called a figure of the first order, or the order of units.

A figure in the second place is a figure of the second order, or the order of tens.

In the third place, of the order of hundreds, etc.

Each place name expresses a specific value or number. As, unit means the first whole number and expresses one.

Ten means ten times one, or a value equal to ten ones.

Hundred means ten times ten, or a value equal to ten times ten, single things, individuals or units.

Thousand means ten hundred single things or units.

Ten thousand means ten thousand single things or units.

Hundred thousand means hundred thousand single things or units.

Million means a thousand thousand single things or units.

Ten million means ten thousand thousand single things or units.

Hundred million means ten thousand thousand single things or units.

Billion means one thousand million (1,000,000,000).

Each figure of a number expresses so many units of that order to which it belongs.

For example, one figure standing alone is called a unit, but when two of them stand together the left-hand one expresses so many units of the second order, which is tens, but the right-hand one is still called a unit; thus, 79 is a collection of *nine units* and seven sets of ten units each, or of nine units and seventy units, or of 79 units, and is read seventy-nine.

Where three figures stand together, thus, 346, the third one from the unit figure 6 expresses so many units

of the third order, which is hundreds, and as in this case the figure is 3, three hundred is represented, and the above reads three hundred forty-six.

The fourth figure of a number expresses so many thousands.

The fifth expresses so many tens of thousands.

The sixth expresses so many hundreds of thousands, etc.

The nought (0), usually called cypher, signifies nothing when standing alone, but when it stands with other figures it means something.

For example, the cypher standing alone, thus, 0, means that no units are represented.

And the figure 1 standing alone, thus, 1, denotes one unit only, but by connecting a cypher to the 1, thus, 10, the value of 1 is increased tenfold, making it ten because it is removed one place to the left. Again, 13 standing alone, thus, 13, denotes thirteen units, and by connecting a cypher to it, thus, 130, the figures 13 are removed one place to the left each and thereby given a tenfold value and become one hundred and thirty.

Again, 103 (one hundred and three); here the cypher has a similar significance on the figure 1, causing it to represent one hundred. By referring to page 5 we will see that each three places of figures are separated by a comma (,) and each three places thus separated denote a group, and each group has a name as shown below:

000,	000,	000,	000,
Billions.	Millions.	Thousands.	Hundreds.

The first set of three on the right are hundreds, the next set of three are thousands, the next set of three are millions, and the next set of three are billions.

With the aid of the following table, express in writing the value of the numbers shown:

Hundreds of Billions.	Tens of Billions.	Billions.	Hundreds of Millions.	Tens of Millions.	Millions.	Hundreds of Thousands.	Tens of Thousands.	Thousands.	Hundreds.	Tens.	Units.		
0	0	0,	0	0	0,	0	0	0,	0	0	0,		
–	–	–	–	–	–	–	–	–	–	–	5	Number	1
–	–	–	–	–	–	–	–	–	–	2	5	Number	2
–	–	–	–	–	–	–	–	–	3	4	2	Number	3
–	–	–	–	–	–	–	–	1	6	7	4	Number	4
–	–	–	–	–	–	–	5	4	3	4	0	Number	5
–	–	–	–	–	–	9	6	0	7	8	0	Number	6
–	–	–	–	–	3	7	2	6	9	0	2	Number	7
–	–	–	–	1	5	9	0	8	6	6	0	Number	8
–	–	–	3	0	2	6	0	7	6	0	6	Number	9
–	–	5	0	0	3	0	0	0	0	0	3	Number	10
–	3	2	6	7	3	3	0	0	3	0	0	Number	11
9	9	9	9	9	9	9	9	9	9	9	9	Number	12

EXAMPLE. Read, 463463765322.

First begin and mark off the figures in threes from right to left; thus,

463,463,765,322

and the number reads four hundred and sixty three billion four hundred sixty-three million seven hundred and sixty-five thousand three hundred and twenty-two.

EXAMPLE. Read, 1070008346.

First mark off in threes from right to left as in last example; thus,

1,070,008,346

and the number reads one billion seventy million eight thousand three hundred and forty-six.

Examples for Exercise

Read the following numbers:

1. 4364
2. 1927
3. 9009
4. 434672
5. 6497923
6. 53290678
7. 500490069
8. 5867340068

NOTATION

Notation is the art of writing or otherwise expressing numbers by means of figures.

Example. Express in figures three hundred and twenty-two. *Ans.* 322.

Example. Express in figures three thousand two hundred and twenty-three. *Ans.* 3223.

It is very difficult for those who have had little practice in writing down numbers, to do so correctly; for such the following is recommended, by means of which the art of notation will be made very simple.

Place in a row a number of cyphers (0) and mark them off in threes from right to left with a comma(,); and over the tops of each set of three (groups) note the positions of hundreds, thousands, millions, etc. Thus:

Billions.	Millions.	Thousands.	Hundreds.
0 0 0	0 0 0	0 0 0	0 0 0
	8	0 0 0	0 0 0
	18	0 0 0	0 5 0

Now with the aid of the above express in figures eight million. This is done by using the table as a guide and placing eight million under its proper position as shown

Again express in figures, with the aid of the above, eighteen million and fifty.

This is done by placing eighteen million under its proper position place next the fifty; then fill out the spaces between these figures with cyphers, as above, and it stands 18,000,050, which is the correct expression.

Examples for Exercise

1. Express in figures three thousand seven hundred and twenty-five.
2. Express in figures twelve thousand six hundred.
3. Express in figures three hundred and twenty-two thousand and six.
4. Express in figures six million fifty thousand and twenty.
5. Express in figures thirty-eight million four hundred and twenty thousand three hundred and fifty.
6. Express in figures two hundred and twenty-two million eight hundred and thirty-five thousand one hundred and thirty.

ADDITION

Addition is the art of expressing in one number the units contained in two or more numbers. Making a single number, for instance, express the number of units contained in the numbers 342 and 721.

In addition care must be taken in placing the figures. The unit figure of one line must be placed under the unit figure of the line above it. The same care must be taken in placing the tens, hundreds, thousands, etc. That is, the unit figure in the second line of figures must be

placed directly under the unit figure of the first line of figures, and the unit figure of the third line under the unit figure of the second line, etc.

The same rule must be followed in placing the tens, hundreds, thousands, etc. The tens being placed under the tens of the line of figures above it, likewise the hundreds must be placed under the hundreds of the line above; also the thousands must be placed directly under the thousands of the line above. It does not matter if there are more figures in one line of figures than in another line.

For instance, one line having three figures can be added to a line having four or any number of figures. And the lines of figures in such a sum would be placed thus:

Thousands.	Hundreds.	Tens.	Units.	
7	6	3	2	Line having four figures.
	1	4	2	Line having three figures.

Placing the unit figure of the second line under the unit figure of the first. The tens and hundreds of the second line are likewise placed under the tens and hundreds of the first line as shown.

The following examples will show more fully how the figures in each line are placed:

6342	1	87654216
42	32	439103
791	344	716724332
1002	6778	4986345

And it will be seen thereby, as just explained, that units are placed under units, tens under tens, hundreds under hundreds, etc.

Rules for Adding

Add the right-hand column first and write the unit figure of the sum of the column under it, and add the tens, if any, to the next column. So proceed with all the columns, writing down the unit figure only of the sum of each column, with the exception of the last column, in which case the entire sum of the column is written down.

Example. Add together 43 and 52 and 16 and 8. Proceed by placing each row of figures one under the other, as follows:

Thus,

$$\begin{array}{r} 43 \\ 52 \\ 16 \\ 8 \\ \hline 119 \end{array}$$

Having arranged the numbers as in the example, we first add the units, which is the right-hand column, and we say 8 and 6 are 14 and 2 are 16 and 3 are 19; now in 19 units there are 9 units and 1 ten, so we write the 9 units under the column of units and add the 1 ten to the column of tens, then 1 added to 1 makes 2, and 2 and 5 are 7 and 4 are 11, and in this case the sum of the whole column is written down because it is the last column to be added, and we find when the four numbers are added together they equal the sum of 119.

Example. Add together the following: 346, 794, 19, and 6.

$$\begin{array}{r} 346 \\ 794 \\ 19 \\ 6 \\ \hline 1165 \end{array}$$

Here proceed as before, first by placing the different numbers to be added together in their proper relative places.

Then add first the units, thus, 6 and 9 are 15 and 4 are 19 and 6 are 25. Write the 5 units under the column of units and add the 2 tens to the column of tens, thus, 2 and 1 are 3 and 9 are 12 and 4 are 16. Write the 6 tens under the column of tens and add the 1 hundred to the next column, then 1 and 7 are 8 and 3 are 11; then the sum of this column equals 11 hundreds or one thousand and 1 hundred, in which case we place the 1 hundred under the column of hundreds, and as there is no other column to be added, which, if there was, would be thousands, we place the one thousand in thousands place, and we find the sum of the four numbers, when added together, equals 1165.

Examples. Add together:

643	346	421
752	132	3
16	684	24
8	2	342
1419 *Ans.*	1164 *Ans.*	790 *Ans.*

When adding columns of figures where the sums of the columns will equal three figures or more, the right-hand figure of the sum only is written down, under the column, and the other two figures are added to the next column, as in the above example, where the columns summed up to two figures, the unit figure only was written down and the tens added to the next column.

For example, if it is found that the sum of the column of figures equals 342, the right-hand figure 2 only is put down, and the 34 is added to the next column, whose

sum we will suppose equals 1436, with the addition of the 34. Then the right-hand figure 6 of the sum of the column is written down only, and the 143 is added to the next column, which, if it happened to be the last column, would have its whole sum written under it.

Examples for Practice

Add together:

(1)	(2)	(3)	(4)
3421	7996	6754	694004
6724	8432	4576	426772
5431	6013	5467	324584
2031	0421	9100	953267
17607	22862	25897	2398627

(5)	(6)	(7)
3421	7899	8998
7996	9889	5496
6724	8998	8448
6999	5496	9779
8768	8448	8889
9999	7997	7899
8888	9888	9889
7777	6989	9896
5989	8888	8888
9898	9999	9889
7987	9999	8998
6893	8768	9999
5496	6999	8768
8998	8626	7688
9889	7997	8876
7899	3421	8768
123621	130301	141168

Examples for Exercise

Add together:

1. Thirty-two thousand seven hundred and two; sixteen thousand four hundred and sixty-seven; nine thousand three hundred and forty-four; forty-two thousand one hundred and sixty-four.

2. One million three hundred and sixty-seven thousand four hundred and twenty-two; five million four hundred thousand; three hundred and sixty-three; one thousand three hundred and forty-two; seven million one hundred and sixteen thousand and forty-two; four million eighteen thousand seven hundred and fifty-three.

3. Six hundred and ninety-four thousand and four; four hundred and twenty-six thousand seven hundred and seventy-two; three hundred and twenty-four thousand five hundred and eighty-four; nine hundred and fifty-three thousand two hundred and sixty-seven.

4. Five million four hundred and sixty thousand seven hundred and twenty; seven million thirty-two thousand and thirty; two million three hundred and seventy-two thousand four hundred and fifty; one hundred and twelve million three hundred and sixty-two thousand nine hundred and seventy-two.

5. Seven hundred and twenty-two million three hundred and thirty-three thousand five hundred and sixty-seven; two million thirty thousand and thirty; seventeen million seven hundred and twenty thousand six hundred and seventy-two; forty-two million five hundred and eighty-two thousand three hundred and thirty-six.

Find the sum of:

1. 4627 and 9824 and 2763 and 9005.

2. 916742 and 7104 and 83 and 7628143.

3. 18926742 and 6742839 and 15078949 and 1672.

SUBTRACTION

Subtraction is the art or process of taking one number or quantity from another number or quantity of the same order, or the operation of finding the difference between two numbers of the same kind. For example, the process of finding the difference between the numbers 1674 and 4236.

Like denominations may be subtracted one from the other only. That is, 25 cents can be taken from 75 cents, but 25 cents cannot be taken from 75 potatoes. Neither can 36 bushels of wheat be taken from 96 bushels of oats, but 36 bushels of oats may be taken from 96 bushels of oats.

That number or quantity to be subtracted from is called the minuend, and that number or quantity which is taken is called the subtrahend. And the result of the operation of taking one number from another is called the difference.

Minuend means to be diminished.

Subtrahend means that number which is taken from another.

Only units of the same order can be subtracted. That is, ones can be taken from ones; tens from tens; hundreds from hundreds, etc.

Example. Find the difference between 684 and 342.

Proceed thus:

First place the subtrahend 342 under the minuend 684, arranging the figures in columns so that units come under units, tens under tens, and hundreds under hundreds. As follows:

$$\begin{array}{rl} 684 & \text{Minuend} \\ \underline{342} & \text{Subtrahend} \\ 342 & \end{array}$$

Then draw a line underneath, thus ———

Proceed now to subtract, beginning with the column on the right, saying 2 ones from 4 ones leaves 2 ones, which write beneath in ones place. So proceed with tens, saying 4 tens from 8 tens leaves 4 tens, which write under tens place; likewise proceed with the hundreds and say, 3 hundreds from 6 hundreds leaves 3 hundreds, which write under the hundreds place, and the difference is 342 as shown in example.

Example. Subtract 264 from 498.

Here proceed as before, first by placing 264, the subtrahend, under 498, the minuend. Thus:

498	Minuend
264	Subtrahend
234	Difference

Then say, 4 ones from 8 ones leaves 4 ones, which write under the ones place; then 6 tens from 9 tens leaves 3 tens, which write under the tens place; then 2 hundreds from 4 hundreds leaves 2 hundreds, which write under the hundreds place, and the difference is 234.

The work of subtraction may be proven by adding together the subtrahend and the difference, and if the sum thus obtained is equal to the minuend the operation has been correctly performed.

Thus, to prove the work of the above add together 264, the subtrahend, and 234, the difference, and the sum 498 equals the minuend.

Examples for Exercise

1. Subtract 462 from 896. *Ans.* 434.
2. Subtract 256 from 467. *Ans.* 211.
3. Subtract 372 from 985. *Ans.* 613.

4. Subtract 137 from 249. *Ans.* 112.

5. Subtract 283 from 999. *Ans.* 716.

6. Subtract 567 from 878. *Ans.* 311.

7. If six apples cost 18 cents and 7 oranges cost 6 cents, how many more cents did the apples cost than the oranges. *Ans.* 12.

8. A boy had 46 marbles and he gave away 6 to one friend, 9 to another; how many marbles had he left? *Ans.* 31.

9. John is 37 years old and Henry is 16, what is the difference in the ages? *Ans.* 21.

10. A man had 75 dollars and he spent 24; how many dollars had he left? *Ans.* 51.

11. Bought 100 pounds of iron for 90 dollars and sold it for 60 dollars; how much was lost on the transaction? *Ans.* 30.

If any order of the minuend has less units than the same order of the subtrahend, increase its units by ten, and subtract; consider the unit of the next minuend order one less and proceed as before. In other words, when it is found that the figure in the minuend to be taken from is less than the figure in the subtrahend, which is to be taken from it, increase then the units of that figure of the minuend ten times, and the next figure in the minuend to be subtracted from is decreased one unit.

For instance: From 37
Take 18
19

From 7 ones we cannot take 8 ones, so 7 is increased by 10 units and becomes 17 units. We now say 8 units from 17 units leaves 9 units, which write down. Now the next figure 3 is decreased by one unit, so becomes 2; then we say 1 ten from 2 tens leaves 1 ten, which write

down, and the difference between 37 and 18 is 19, as shown in example.

Example. From 566
Take 388
178

Here as in the previous example, the unit 8 in the subtrahend is larger than the unit 6 in the minuend, so we add 10 to the 6 and consider it 16 units; then say 8 units from 16 units leaves 8 units, which write underneath. Now the next figure 6 is to be considered 5, because, as just explained, 1 unit must be taken from this unit when the unit before it is increased by 10 units; it then becomes 5 instead of 6. Now 8 tens from 5 tens cannot be taken, so we increase the 5 tens by 10, and it then becomes 15 tens; so we say 8 tens from 15 tens leaves 7, which write underneath. Now the next order 5 is to be considered 1 less for the same reason that the last order 6 was considered 5; then say, 3 hundreds from 4 hundreds leaves 1 hundred, which write down, and the difference is found to be 178 as shown in the example.

Example. From 6605
Take 3767
2838

Seven units cannot be taken from 5 units, so 10 units are added to the 5 units, making it 15 units; then 7 units from 15 units leaves 8 units, which write underneath. Now when the next order to be subtracted from is 0, as in the example, 10 units are likewise added, whereupon the 0 would be increased to 10 tens. Now from these 10 tens 1 unit is taken, because the unit before it was increased 10 units, therefore it becomes 9;

then we say, 6 tens from 9 tens leaves 3 tens, which write underneath the tens place. Then proceed by taking one unit from the next order, making it 5, and as 7 cannot be taken from 5 we add 10 units thereto, making it 15; then say 7 from 15 leaves 8, which write underneath. Then from the next order 6 take 1 unit, which makes it 5; then say 3 from 5 leaves 2, which write underneath, and the difference is 2838, as shown in example.

Examples for Exercise

1. From 397 take 279. *Ans.* 118.
2. From 966 take 788. *Ans.* 178.
3. From 4592 take 2364. *Ans.* 2228.
4. From 6422 take 3188. *Ans.* 3234.
5. From 9263 take 6346. *Ans.* 2917.
6. From 8674 take 5785. *Ans.* 2889.

When any order of the minuend has the same number of units as the same order of the subtrahend, its units are not increased by tens, as was the case in the preceding examples in which the order of the units in the minuend were less than the units of the same order in the subtrahend.

In other words, when the figure to be taken from is the same as the figure which is to be taken from it, no matter what the order is, of the figures which are to be subtracted one from the other, the figure to be subtracted from is unchanged.

For example:	From	14
	Take	4
		10

In this case the unit figures in the minuend and subtrahend, are the same, in which case we say 4 ones from

4 ones leaves 0 ones, which write down in units or ones place. Then there are no tens to be taken from the 1 ten, so we say 0 ten from 1 ten leaves 1 ten, which write underneath in tens place, and the answer is 10 as shown in example.

EXAMPLE.	From	654
	Take	354
		300

Here is an example having two figures in the subtrahend, the same as two figures of the same order in the minuend.

So proceed as in last example by taking 4 units from 4 units, which leaves 0 units, which write underneath in units or ones place; then say 5 tens from 5 tens leaves 0 tens, which write underneath tens place; then say 3 hundreds from 6 hundreds leaves 3 hundreds, which write underneath hundreds place, and the answer is 300, as shown in example.

EXAMPLE.	From	767
	Take	558
		209

In this case the unit figure 7 to be subtracted from is less than the unit figure 8 which is to be subtracted from it, so increase it by 10 units, and it becomes 17 units, from which take the 8 units in the subtrahend and 9 units are left, which write underneath in ones place. Now the next order of the minuend, which is 6, is to be considered one less, which makes it 5; then say 5 tens from 5 tens leaves 0 tens, which write underneath in tens place; then say 5 hundreds from 7 hundreds leaves 2 hundreds, which write down underneath hundreds place, and the answer is 209 as shown in example.

EXAMPLE: What is the difference between

	89645278	
and	65437169	
	24208109	*Ans.*

EXAMPLES FOR EXERCISE

1. What is the difference between 486795 and 245483. *Ans.* 241312.

2. What is the difference between 937256 and 518137. *Ans.* 419119.

3. What is the difference between 76042912 and 537-96878. *Ans.* 2246034.

4. What is the difference between 843676 and 796832. *Ans.* 46844.

5. What is the difference between 26784263 and 25342621. *Ans.* 1441642.

6. What is the difference between 7500476 and 456-7543. *Ans.* 2932933.

MULTIPLICATION

MULTIPLICATION TABLE

1	2	3	4	5	6	7	8	9	10	11	12
2	4	6	8	10	12	14	16	18	20	22	24
3	6	9	12	15	18	21	24	27	30	33	36
4	8	12	16	20	24	28	32	36	40	44	48
5	10	15	20	25	30	35	40	45	50	55	60
6	12	18	24	30	36	42	48	54	60	66	72
7	14	21	28	35	42	49	56	63	70	77	84
8	16	24	32	40	48	56	64	72	80	88	96
9	18	27	36	45	54	63	72	81	90	99	108
10	20	30	40	50	60	70	80	90	100	110	120
11	22	33	44	55	66	77	88	99	110	121	134
12	24	36	48	60	72	84	96	108	120	132	144

Multiplication is a convenient method of finding the sum of any number that has to be added to itself any number of times.

For instance, if we had occasion to find the sum of 6 added to itself 5 times.

Instead of performing the operation thus:

$$\begin{array}{r} 6 \\ 6 \\ 6 \\ 6 \\ \underline{6} \\ 30 \end{array}$$

we perform the operation by the process of multiplication. The 6 is written down once only, and underneath it the 5, underneath which draw a line as shown in the following:

$$\begin{array}{r} 6 \\ \underline{5} \\ 30 \end{array}$$

Proceed then, saying 5 times 6 are 30, which place underneath the line as shown.

It is here seen that both methods give the same results, but that the latter is the more convenient.

Multiplication, then, is the process of finding the amount of one number increased as many times as there are units in another.

In multiplication there are three terms used called the Multiplicand, Multiplier, and the Product.

The Multiplicand is the number to be multiplied.

The Multiplier is the number by which we multiply.

The Product is the answer.

According then to multiplication, one number (called the multiplier) is made to operate on another number

(called the multiplicand) as many times as there are units in the multiplier, and the result of the operation is called the product. As shown in the following example, where 7, the multiplier (the number by which we multiply), operates on 8, the multiplicand (the number to be multiplied), and the result of the operation, 56, is the product.

8	Multiplicand
7	Multiplier
56	Product

Always multiply from right to left.

When arranging the numbers to be multiplied one by the other, care must be taken to place the unit figure of the multiplier under the unit figure of the multiplicand. The same rule must be carried out in placing the tens, hundreds, thousands, etc.; that is, tens under tens, hundreds under hundreds, and thousands under thousands.

Example. Multiply 34231 by 2.

Proceed as follows: Write down the multiplicand 34231, under the unit figure 1 of which place the multiplier 2, underneath which draw a line as shown.

34231	Multiplicand
2	Multiplier
68462	Product

Then after arranging the sum thus, proceed to multiply from right to left, the figures in the multiplicand by the figure in the multiplier, saying 2 times 1 are 2, which set down underneath the 1; then say 2 times 3 are 6, which set down underneath the 3; then say 2 times 2 are 4, which set down underneath the 2; then say 2

times 4 are 8, which set down underneath the 4; then say 2 times 3 are 6, which set down underneath the 3.

Examples for Practice

Multiply	34213	4324312
By	3	2
	102639	8648624

When numbers are multiplied one by the other, the unit figure only of each product is set down, and the tens are added to the product of the next figure to the left, with the exception of the last figure to be multiplied, in which case the product in full is set down.

Example. Multiply 642 by 3.

Here, as in the preceding example, arrange the sum, placing the multiplier 3 under the unit figure 2 of the multiplicand, and drawing a line underneath. Thus:

$$\begin{array}{r} 642 \\ 3 \\ \hline 1926 \end{array}$$

Proceed by multiplying the 2 of the multiplicand by the multiplier 3, saying 3 times 2 are 6, which set down directly under the 3; then multiply the 4 in the multiplicand by 3, saying 3 times 4 are 12, but set down the unit or right-hand figure 2 only underneath the 4, and add the left-hand figure of the product, which is 1, to the next product. We then proceed, multiplying the 6 in the multiplicand by the multiplier 3, saying 3 times 6 are 18, to which, as before stated, 1 is to be added, making it 19, which is set down in full, because it is the product of the last figure to be multiplied.

Example. Multiply 64395 by 4.

Proceed as before by placing the multiplier under the unit figure of the multiplicand, drawing a line underneath.

$$\begin{array}{r} 64395 \\ 4 \\ \hline 257580 \end{array}$$

Then multiply the 5 in the multiplicand by 4, saying 4 times 5 are 20, and set down the 0 (cypher) directly underneath the 4. We then multiply the 9 in the multiplicand, saying 4 times 9 are 36, to which add the 2 tens of the last product, making 38; setting down the 8 only of this product, we add the 3 to the next product; saying 4 times 3 are 12 and 3 are 15, we set down the 5 only and add the 1 to the next product and proceed, saying 4 times 4 are 16 and 1 are 17, the right hand or unit figure of which set down only, and add the 1 to the next product, saying 4 times 6 are 24 and 1 are 25, which, as it completes the multiplication we set down in full and the product is 257580, as shown.

Examples for Practice

Multiply	132	432	212
By	3	2	4
	396	864	848
Multiply	634	732	845
By	2	3	5
	1268	2196	4225

Multiply	9654321672
By	7
	67580251704

Example. Multiply 4635 by 11.

Here is an example having two figures in the multiplier, in which case, when the multiplier does not exceed 12, the operation is the same as in the preceding examples.

$$\begin{array}{r} 4635 \\ 11 \\ \hline 50985 \end{array}$$

Having arranged the numbers to be multiplied one by the other, placing the unit figure of the multiplier under the unit figure of the multiplicand, and the tens of the multiplier under the tens of the multiplicand, we multiply the 5 in the multiplicand by 11, saying 11 times 5 are 55; set down the right-hand figure only. We then say, 11 times 3 are 33, to which the left-hand figure 5 of the preceding product is added, making 38; we set down the 8 under the 3 of the multiplicand. Now multiply 6 by 11, saying 11 times 6 are 66 and 3 are 69, the 3 being the left-hand figure of the preceding product; set down the 9 only of the product and add the 6 to the next product. Now multiply 4 by 11, saying 11 times 4 are 44 and 6 are 50, which set down in full as it finishes the multiplication, and the product is 50985.

Example. Multiply 6324 by 12

$$\begin{array}{r} 12 \\ \hline \end{array}$$

Set down the multiplicand and the multiplier as before, placing the unit figure of the multiplier under the unit figure of the multiplicand, and the tens of the multiplier under the tens place of the multiplicand. Thus:

$$\begin{array}{r} 6324 \\ 12 \\ \hline 75888 \end{array}$$

Then proceed to multiply each figure of the multiplicand by the multiplier, saying 12 times 4 are 48, of which we set down the right-hand figure 8 only. We then multiply the 2 in the multiplicand by 12, saying 12 times 2 are 24, to which 4, the left-hand figure of the preceding product, is added, making 28; set down the 8 only. We then multiply 3 by 12, saying 12 times 3 are 36 and 2 (the left-hand figure of preceding product) are 38; set down the 8 only of this product. We then multiply the 6 in the multiplicand by 12, saying 12 times 6 are 72 and the 3 of the preceding product are 75, which is the product of the last figure to be multiplied and is set down in full.

The whole product then is 75888.

Examples for Practice

Multiply	52436
By	10
	524360
Multiply	63425
By	12
	761100
Multiply	724302
By	11
	7967322

When the multiplier consists of more than one figure (and exceeds 12), each figure of the multiplicand is multiplied by each figure of the multiplier.

For instance, if we had occasion to multiply 463 by 24, in which case the multiplier exceeds 12, we would proceed after arranging the numbers to be multiplied, thus:

```
  463
   24
 ----
 1852
 926
-----
11112
```

by multiplying each figure of the multiplicand 463 by the unit figure 4 of the multiplier first. Then in like manner each figure of the multiplicand would be multiplied by the 2 of the multiplier.

The products obtained by the operation of each figure of the multiplier upon the multiplicand are called partial products, and the right-hand figure of each partial product is placed directly under the figure of the multiplier that produces it.

Thus, in the above example, we first multiplied each of the figures 463 of the multiplicand by the figure 4 of the multiplier, and by the process got the partial product 1852, the unit figure 2 of which is placed directly under the figure 4 of the multiplier.

We then multiplied each of the figures 463 by 2 and get a second partial product 926, the unit figure 6 of which is placed directly under the figure 2 of the multiplicand which produced it.

To get the whole product add together the several partial products.

EXAMPLE. Multiply 433 by 32. Write the multiplier and multiplicand as before.

```
  433
   32
-----
  866
 1299
-----
13856
```

Proceed to multiply each figure of the multiplicand by each figure of the multiplier successively. Beginning with the unit figure 2 of the multiplier we multiply each figure of the multiplicand, saying 2 times 3 are 6, which set down underneath the multiplier 2. Then multiply the next figure 3 of the multiplicand by the unit figure 2 of the multiplier, saying 2 times 3 are 6, which set down. Then multiply the figure 4 of the multiplicand by the unit figure 2 of the multiplier, saying 2 times 4 are 8, which set down.

By the operation of the figure 2 of the multiplier upon each figure of the multiplicand, the partial product 866 is obtained.

Proceed now to multiply each figure of the multiplicand by the next figure 3 of the multiplier, saying 3 times 3 are 9, and, as before stated, the right-hand figure of each partial product is placed directly under the figure of the multiplier which produces it; the 9 is placed under the 3 of the multiplier.

Now multiply the next figure 3 of the multiplicand by the figure 3 of the multiplier, saying 3 times 3 are 9, which set down underneath the next figure to the left of the preceding partial product. Now we multiply the next figure 4 of the multiplicand by the figure 3 of the multiplier, saying 3 times 4 are 12, which set down in full, and by the operation of the figure 3 of the multiplier upon each figure of the multiplicand we have obtained another partial product, 1299, underneath which, as it is the last partial product to be obtained, we draw a line and proceed to get the whole product by adding the partial products together as in addition, and we have for the whole product, 13856, as shown.

Example. Multiply 543 by 43.

Here arrange the numbers to be multiplied one by the other as before.

$$\begin{array}{r} 543 \\ 43 \\ \hline 1629 \\ 2172 \\ \hline 23349 \end{array}$$

And this being another example where the multiplier exceeds 12, we proceed as before to get the product by making each figure of the multiplier operate upon each figure of the multiplicand successively. Beginning with the figure 3 of the multiplier, first we multiply the 3 of the multiplicand, saying 3 times 3 are 9, which set down directly underneath the 3 of the multiplier, which produced it; then multiply the next figure of the multiplicand by the figure 3 of the multiplier, saying 3 times 4 are 12; of this product we set down the 2 and add the 1 to the next product and proceed, saying 5 times 3 are 15 and 1 are 16, which set down in full.

Now proceed to multiply by the next figure 4 of the multiplier each figure of the multiplicand, saying 4 times 3 are 12; here set down the right-hand figure 2 under the figure 4 which produced it, and add to the next product the left-hand figure 1 and proceed, saying 4 times 4 are 16 and 1 are 17; set down the 7 only under the next place to the left of the preceding partial product 1629, and to the next product add the 1; proceed, saying 4 times 5 are 20 and 1 are 21, which set down in full.

Now having obtained the partial products, draw a line underneath as before and proceed to add them together to get the whole product, and as shown the product of 543 multiplied by 43 is 23349.

Examples for Practice

```
Multiply    524          467
By           34           53
          -----        -----
           2096         1401
          1572         2335
          -----        -----
          17816        24751

Multiply    693          396
By           91           82
          -----        -----
            693          792
           6237         3168
          -----        -----
          63063        32472
```

Example. Multiply 5943 by 434.

Here is an example having three figures in the multiplier.

```
   5943
    434
-------
  23772
 17829
23772
-------
2579262
```

After arranging the multiplier under the multiplicand, placing units under units, tens under tens, and hundreds under hundreds, proceed to multiply each figure of the multiplicand by each figure of the multiplier, as in preceding examples, placing the right-hand figure of each of the three partial products directly under the figure of the multiplier which produces it. That is, place the right-hand figure obtained by the operation of the unit figure 4 of the multiplier upon each figure of the multiplicand directly under the 4. Place the right-hand

figure of the partial product obtained by the operation of the figure 3 of the multiplier upon each figure of the multiplicand under the figure 3 of the multiplier which produces it, and place the right-hand figure of the partial product obtained by the operation of the figure 4 of the multiplier upon each figure of the multiplicand directly under the figure 4 of the multiplier which produces it.

Having obtained the partial products, add them together and we have the whole product of 5943 multiplied by 434 equal to 2579262.

When numbers are multiplied one by the other, the product is the same whatever the order of multiplying them. That is, the product of 642 multiplied by 64 is the same as the product of 64 multiplied by 642, as shown by the following examples:

```
 642          64
  64         642
----        ----
2568         128
3852        256
----        384
41088       ----
            41088
```

For convenience, however, it is customary to multiply the larger number by the smaller.

Method of Operation where there are Cyphers in the Multiplier.

Example. Multiply 5634 by 403.

Here we multiply by the figures of the multiplier only, placing the right-hand or unit figure of each partial product directly under the figure of the multiplier which produces it, and pass over the cypher or cyphers in the following manner:

After arranging the numbers to be multiplied one by the other, thus:

```
   5634
    403
 ------
  16902
 22536
 -------
 2270502
```

we proceed to multiply first by the figure 3 of the multiplier and obtain by the operation the partial product 16902.

Now we come to the cypher (0), which we pass over and multiply by the next figure 4, taking care to place the right-hand figure 6 of the partial product 22536, obtained by the multiplication, directly under the figure 4 of the multiplier which produces it.

Now having obtained the partial products, add same together and the whole product is seen to be 2270502.

Example. Multiply 9436782 by 24003.

Arrange the numbers to be multiplied one by the other as before. Thus:

```
      9436782
        24003
 ------------
     28310346
   37747128
  18873564
 ------------
 226511078346
```

Proceed now to multiply the figures of the multiplicand by the figure 3 of the multiplier, by which operation is obtained the partial product 28310346, the right-hand figure 9 of which is placed directly under the 3 of the multiplier which produces it. We now come to the

cyphers of the multiplier, two of them, which we pass over and use the figure 4 as the next multiplier. By the operation of the figure 4 upon the multiplicand, the partial product 37747128 is obtained, the right-hand figure 8 of which place directly under the figure 4 of the multiplier which produces it. Proceed now to multiply each figure of the multiplicand by the figure 2 of the multiplier, by which operation is obtained the partial product 18873564, the right-hand figure 4 of which place directly under the 2 of the multiplier which produces it.

Having now obtained the several partial products, add them together and we have the whole product as shown, 226511078346.

Examples for Practice

Multiply	4532	2354
By	203	303
	13596	7062
	9064	7062
	919996	713262

Multiply	564672	679423657
By	23004	4000003
	2258688	2038270971
	1694016	2717694628
	1129344	2717696666270971
	12989714688	

Example. Multiply 425326 by 5300.

Here is an example having cyphers (0) on the right of the multiplier. In which case the first significant figure of the multiplier (from right to left) is placed directly

under the first figure of the multiplicand from right to left.

Multiply by the significant figures only and annex as many cyphers to the product as there are cyphers on the right of the multiplier. Proceed now to multiply, arranging the first figure 3 of the multiplier under the first figure 6 of the multiplicand. Thus:

```
  425326
    5300
  -------
 1275978
2126630
----------
2254227800
```

Pass over the cyphers and, as before stated, multiply by the significant figures only.

First multiply the multiplicand 425326 by the figure 3 of the multiplier 5300, by which operation we obtain the partial product 1275978, the right-hand figure 8 of which is placed directly under the figure 3 of the multiplier which produced it.

Multiply now the multiplicand by the next figure 5 of the multiplier, by which operation is obtained the partial product 2126630, the cypher (0) of which is placed directly under the figure 5 of the multiplier which produced it. Add together the partial products thus obtained, to which annex the cyphers (two of them) which are at the right of the multiplier, and we obtain the whole product 2254227800 as shown.

EXAMPLE. Multiply 53267 by 4700.

Arrange the numbers to be multiplied as before, placing the first figure 7 of the multiplier 4700 under the first figure 7 of the multiplicand, and place the next figure 4 of the multiplier one place to the left. Thus:

```
   53267
     4700
  ------
  372869
 213068
 ---------
 250354900
```

Proceed now to multiply by the figure 7 of the multiplier first, then by the figure 4.

Add together the partial products thus obtained, to which annex the cyphers on the right of the multiplier, and by the operation we obtain the product 250354900 as shown.

EXAMPLES FOR PRACTICE

```
Multiply   135672         276354
By             40            630
          -------      ---------
          5426880         829062
                         1658124
                       ---------
                       174103020

Multiply   4568942    79235467
By            7200       30000
          --------   -------------
           9137884   2377064010000
          31982594
          -----------
          32896382400

Multiply   328671     1763254
By            100     1000000
          --------   -------------
          32867100   1763254000000
```

PROCESS. When there are cyphers on the right of both multiplicand and multiplier, set down the significant figures of the multiplier under the significant figures of the multiplicand, placing the first (from right to left)

significant figure of the multiplier directly under the first (from right to left) significant figure of the multiplicand. Annex to the product obtained by the operation of the multiplier upon the multiplicand as many cyphers as there are on the right of the multiplicand and multiplier.

Example. Multiply 64200 by 340.

Arrange the multiplier 340 under the multiplicand 64200, placing the figure 4 of the multiplier (which is the first figure from right to left) under the figure 2 of the multiplicand (which is the first figure of the multiplicand, from right to left. Thus:

$$\begin{array}{r} 64200 \\ 340 \\ \hline 2568 \\ 1926 \\ \hline 21828000 \end{array}$$

Proceed now to multiply.

Multiplying the figures 642 of the multiplicand by the figure 4 of the multiplier, we obtain the partial product 2568, the right-hand figure 8 of which is placed directly under the figure 4 of the multiplier which produces it.

Now multiply the figures 642 of the multiplicand by the figure 3 of the multiplier, by which operation is obtained the partial product 1926, the figure 6 of which is placed directly under the figure 3 of the multiplier which produces it.

Proceed now by adding together the partial products obtained. By so doing we get 21828, to which, as before stated, the cyphers on the right of the multiplicand and multiplier are annexed. We then have, by annexing the cyphers, the whole product 21828000 as shown.

Example. Multiply 80246000 by 200400.

Here proceed as before, placing the first significant figure 4 of the multiplier under the first figure 6 of the multiplicand. Thus:

```
   80246000
     200400
 ----------
    320984
 160492
 -------------
 16081298400000
```

Proceed now to multiply 80246 of the multiplicand by the figures 4 and 2 of the multiplier.

By the operation of the figure 4 of the multiplier upon the figures 80246 of the multiplicand is obtained the partial product 320984, the right-hand figure 4 of which is placed directly under the figure 4 of the multiplier which produced it.

Next in the multiplier are two cyphers, which pass over in the operation. We then multiply by the figure 2, by which operation is obtained the partial product 160492, the right-hand figure 2 of which is placed directly under the 2 of the multiplier which produced it.

Now add together the partial products thus obtained, to which annex as before the cyphers on the right of the multiplicand and multiplier, and as shown the whole product of 80246000 multiplied by 200400 is 16081298400000.

Examples for Practice

```
Multiply      4020300
By               2309
             --------
               361827
            120609
           80406
           ----------
           9282872700
```

```
Multiply     5003600000          3060402
By           2063100              3002010000
             __________          __________
             50036               3060402
           150108              6120804
          300216             9181206
         100072              ______________
         ____________        9187357408020000
         10322927160000000
```

Examples for Exercise

1. 45673 by 12
2. 567346 by 342
3. 760263 by 3604
4. 4200600 by 3002000
5. 954673000 by 700730

DIVISION

Division is the process of dividing, or separating into parts. The process of finding the number of times one number is contained in "another number." Finding, for instance, the number of times 4 units are contained in 20 units.

There are three terms used in division, called the Divisor, the Dividend, the Quotient.

The Divisor is the name applied to that number by which we divide.

The Dividend is the name applied to that number which is divided or separated into parts.

The Quotient signifies the number of times the Divisor is contained in the Dividend.

In arranging numbers to be divided one by the other the divisor is placed on the left of the dividend, and the divisor and dividend are separated by a curved line, thus,). When the divisor does not exceed 12 the operation of dividing is performed by a process called "Short Division."

EXAMPLE. Divide 8 by 4.

Proceed as follows:

Set down the 4, after which draw a curved line, on the right hand of which line place the figure 8, under which draw a line, thus: ——

The example will then be set down as follows:

$$\text{Divisor}\quad 4\overline{)8}\quad \text{Dividend}$$
$$2\quad \text{Quotient}$$

Proceed now to divide the figure 4 (the divisor) into the figure 8 (the dividend), saying 4 into 8 goes 2 times.

The figure 2 thus obtained is the "quotient" and is placed under the dividend figure 8, being separated therefrom by a line as shown.

EXAMPLE. Divide 6 by 3.

Arrange the divisor and dividend as before. Thus:

$$\text{Divisor}\quad 3\overline{)6}\quad \text{Dividend}$$
$$2\quad \text{Quotient}$$

Proceed then to divide the dividend 6 by the divisor 3, saying 3 into 6 goes 2 times.

The 2 thus obtained is the quotient and is placed directly under the dividend figure 6.

Always divide from left to right.

EXAMPLE. Divide 46 by 2.

Arrange the divisor 2 and the dividend 46 as before. Thus:

$$2\overline{)46}$$
$$23$$

Proceed to divide the divisor 2 into the left-hand figure 4 of the dividend first, saying 2 into 4 goes 2 times,

which set down underneath the 4. Then divide the next figure 6 of the dividend by the divisor 2, saying 2 into 6 goes 3 times, which set down underneath the 6, and, as shown, the quotient thus obtained is 23, which signifies that 2 is contained in 46, 23 times.

Example. Divide 462 by 2.

Arrange the divisor and dividend as before.

$$2\overline{)462}$$
$$231$$

Then proceed to divide.

Taking the left-hand figure 4 of the dividend first, say 2 into 4 goes 2 times, which place under the 4. Now divide the next figure 6 of the dividend by the divisor 2, saying 2 into 6 goes 3 times; place the 3 under the 6. Then proceed to divide the next figure 2 of the dividend by the divisor 2, saying 2 into 2 goes 1 times, place the 1 obtained under the figure 2, and by the operation is obtained the quotient 231, as shown.

Examples for Exercise

Divide 6482 by 2. Thus:

$$2\overline{)6482}$$
$$3241$$

Example. Divide 36366 by 3. Thus:

$$3\overline{)36366}$$
$$12122$$

If there is a remainder after dividing the first or any of the following figures of the dividend, the remainder is prefixed to (placed to the left of) the next figure of the dividend.

For instance, if there was occasion to divide 74 by 2, Thus:

$$2\underline{)74}$$
$$37$$

the divisor 2 is contained in the first figure 7 of the dividend 3 times and 1 over. Place the 3 in the quotient under the 7 and place the 1 which was left over on the left of the next figure 4 of the dividend. We then say 2 is contained in 14 seven times; place the 7 thus obtained in the quotient under the 4; we have then in the quotient 37 as shown, which shows when there is a remainder it is prefixed to the next figure of the dividend, and the divisor is made to operate in the number thus formed.

Example. Divide 762 by 6.

Arrange the example as before. Thus:

$$6\underline{)762}$$
$$127$$

Proceed then to divide, saying 6 is contained in 7 1 time and one over.

Write the quotient figure 1 directly under the 7 and imagine the remainder 1 to be placed to the left of the next figure 6 of the dividend, thus forming the number 16. Inquire then the number of times 6 the divisor is contained in 16, which is found to be 2 times and 4 over. Place the quotient figure 2 under the 6 of the dividend, and to the next figure 2 of the dividend the remainder 4 is prefixed. We then have 42.

Now divide 6, the divisor, into 42, saying 6 into 42 goes 7 times; place the figure 7 under the figure 2 of the dividend, and, as shown, the quotient is 127.

EXAMPLE. Divide 948 by 4.

$$\begin{array}{r} 4\underline{)948} \\ 237 \end{array}$$

Having arranged the numbers to be divided one by the other, proceed to divide, saying 4 is contained in 9 2 times and 1 over. Place the quotient figure 2 under the dividend figure 9 and prefix to the next figure 4 of the dividend, the remainder 1 making 14.

We now divide the divisor 4 into the number 14 thus obtained, saying 4 is contained in 14 3 times and 2 over. Place the quotient figure 3 under the figure 4 of the dividend, and to the next figure 8 of the dividend prefix the remainder 2, making 28.

Divide now 4, the divisor, into 28, saying 4 into 28 goes 7 times, which place underneath the dividend figure 8 and which completes the operation.

EXAMPLES FOR EXERCISE

$$\begin{array}{r} 3\underline{)4674} \\ 1558 \end{array} \qquad \begin{array}{r} 4\underline{)6256} \\ 1564 \end{array} \qquad \begin{array}{r} 5\underline{)7065} \\ 1413 \end{array}$$

$$\begin{array}{r} 6\underline{)68592} \\ 11432 \end{array} \qquad \begin{array}{r} 7\underline{)792582} \\ 113226 \end{array}$$

PROCESS. When the left-hand figure of the dividend is less than the divisor, annex it to the next figure or figures of the dividend, if more than one figure is required to allow the divisor to operate in it.

The quotient figure is placed directly under the last figure, which is annexed to the left-hand figure of the dividend.

EXAMPLE. Divide 651 by 7.

Arrange the divisor 7 and dividend 651 as before. Thus:

$$\begin{array}{r} 7\underline{)651} \\ 93 \end{array}$$

Proceed then to divide.

It is seen that the divisor 7 is greater than the left-hand figure 6 of the dividend, in which case the next figure 5 of the dividend is annexed to the 6, making 65. Divide now by the 7, saying 7 is contained in 65 9 times and 2 over. Place the quotient figure 9 directly under the figure 5 of the dividend, and prefix the remainder 2 to the next figure 1 of the dividend. By so doing we have 21, in which 7 is contained 3 times. Place the 3 under the 1 of the dividend and the division is completed.

Example. Divide 6344 by 8.

Arrange the numbers to be divided one by the other. Thus:

$$\begin{array}{r} 8\underline{)6344} \\ 793 \end{array}$$

The left-hand figure 6 of the dividend is less than the divisor 8, so to it we annex the next figure 3 of the dividend, making 63.

Inquire now how many times the divisor 8 is contained in 63, saying 8 goes into 63 7 times and 7 over (remainder).

Place the quotient figure 7 under the 3 of the dividend, and prefix the remainder 7 to the next figure 4 of the dividend, making 74.

Inquire now the number of times the divisor 8 is contained in 74, saying 8 into 74 goes 9 times and 2 over. Place the quotient figure 9 obtained under the figure 4 of the dividend, and prefix the remainder 2 to the next figure of the dividend, by doing which is obtained 24.

Divide this number 24 by the divisor 8, saying 8 into 24 goes 3 times. Place the quotient figure 3 under the 4 and the division is completed.

Example. Divide 11424 by 12.

$$\begin{array}{r} 12\overline{)11424} \\ 952 \end{array}$$

It is seen that the divisor 12 is greater than the two figures on the left of the dividend, so the next figure 4 is annexed thereto, making 114. Proceed now to divide by the divisor 12, saying 12 into 114 goes 9 times and 6 over. Place the quotient figure 9 directly under the last figure (4) which was annexed to the two figures 11 of the dividend as the first figure of the quotient. By prefixing the remainder 6 to the next figure of the dividend, we have 62, which contains the divisor 12 5 times and 2 over.

Place the quotient figure 5 under the 2 of the dividend, and to the next figure 3 of the dividend prefix the remainder 2, making 24. Divide now the number 24 by the divisor 12, saying 12 into 24 goes 2 times. Place the quotient figure 2 under the 4 and the division is completed.

Examples for Exercise

$$\begin{array}{r} 6\overline{)3254214} \\ 542369 \end{array} \qquad \begin{array}{r} 7\overline{)23541} \\ 3363 \end{array}$$

$$\begin{array}{r} 8\overline{)659696} \\ 82462 \end{array} \qquad \begin{array}{r} 9\overline{)82368} \\ 9152 \end{array}$$

$$\begin{array}{r} 12\overline{)1105462128} \\ 92121844 \end{array}$$

Process. When the divisor is greater than the figure

of the dividend to be divided, place in the quotient a cypher (0) directly under the figure, then to proceed with the division this figure is prefixed to the next figure of the dividend. The divisor is then made to operate in the new number thus formed.

Example. Divide 3624 by 3.

Arrange the divisor and dividend as before

$$\begin{array}{r} 3\overline{)3624} \\ 1208 \end{array}$$

Proceed now to divide, saying 3, the divisor, is contained in the figure 3 of the dividend 1 time.

Place the figure 1 in the quotient under the figure 3 of the dividend.

Then divide the next figure 6 of the dividend by the divisor 3, saying 3 is contained in 6 2 times.

Place the quotient figure 2 obtained under the figure 6 of the dividend.

It will be observed that the next figure 2 of the dividend is less than the divisor 3. In which case place directly under the figure a cypher (0). Consider the figure 2, now, to be prefixed (placed before) to the next figure 4 of the dividend, making 24.

Proceed now to make the divisor 3 operate in the new number 24 thus obtained, saying 3 into 24 goes 8 times.

Place the quotient figure 8 under the dividend figure 4 and the division is completed.

Example. Divide 243648 by 12.

$$\begin{array}{r} 12\overline{)243648} \\ 20304 \end{array}$$

Proceed to divide as follows:

Inquire the number of times the divisor 12 is contained

in the two left-hand figures 24 of the dividend, saying 12 into 24 goes 2 times.

Place the quotient figure 2 underneath the figure 4 of the dividend. The next figure 3 of the dividend is less than the divisor 12, in which case say 12 into 3 goes 0 times. Place the cypher (0) thus obtained directly under the figure 3 of the dividend and consider this figure 3 as prefixed to the next figure 6 of the dividend, making 36.

Now divide this number 36 by the divisor 12, saying 12 into 36 goes 3 times.

Place the quotient figure 3 obtained directly under the figure 6 of the dividend.

The next figure 4 of the dividend is less than the divisor, in which case place directly under it a cypher (0) in the quotient and consider the figure 4 to be annexed to the next figure 8 of the dividend.

Proceed now to divide the number 48 thus obtained by the divisor 12, saying 12 into 48 goes 4 times.

Place the quotient figure 4 directly under the figure 8, and the division is completed.

Examples for Practice

5)402010	6)481236	7)700245
80402	80206	100035
8)643424	11)10124313155	12)112862496
80428	920392105	9405208

When, after dividing the last figure of the dividend there is a remainder, the remainder is placed at the right of the quotient and underneath it set the divisor. The remainder and divisor when thus placed are separated by a short horizontal line (—).

Example. Divide 38 by 3.

Arrange the divisor and dividend as before.

$$\begin{array}{r} 3\underline{)38} \\ 12\tfrac{2}{3} \end{array}$$

Divide the dividend figure 3 by the divisor 3, saying 3 into 3 goes 1 time.

Place the figure 1 obtained in the quotient.

Then divide the next figure 8 of the dividend by the divisor 3, saying 3 into 8 goes 2 times and 2 over (remainder).

Place the quotient figure 2 underneath the figure 8 of the dividend, and place the remainder 2 with the divisor on the right of the quotient as shown.

Example. Divide 4023 by 5.

Arrange the numbers to be divided one by the other. Thus:

$$\begin{array}{r} 5\underline{)4023} \\ 804\tfrac{3}{5} \end{array}$$

Proceed to divide, saying 5 into 40 goes 8 times. Place the 8 obtained in the quotient.

Then say 5 into 2 goes 0 times.

Place the cypher (0) underneath the figure 2 of the dividend.

Then say 5 into 23 goes 4 times and 3 over.

Place the figure 4 obtained in the quotient underneath the figure 3 of the dividend. And the figure 3 which was left over, is a remainder, and is placed on the right of the quotient, having underneath it the divisor and between them a short horizontal line as shown in the example.

Examples for Practice

$$5)\underline{402013} \quad 80402\tfrac{3}{5} \qquad 6)\underline{481237} \quad 80206\tfrac{1}{6} \qquad 7)\underline{700243} \quad 100034\tfrac{5}{7} \qquad 8)\underline{643226} \quad 80403\tfrac{2}{8}$$

$$11)\underline{10124313158} \quad 920392105\tfrac{3}{11} \qquad 12)\underline{112862492} \quad 9405207\tfrac{8}{12}$$

To divide by any number up to 12, having a cypher (0), or any number of cyphers after it.

That is, to divide by 2 with a cypher (0) or cyphers after it which would be either 20, 200, 2000, etc., or 5 with a cypher or any number of cyphers after it, or 6 with a cypher or any number of cyphers after it, as, 60, 600, 6000, etc., up to 12 with a cypher or any number of cyphers after it. As 120, 1200, 12000, 120000, etc.

Mark off from the right of the dividend as many figures as there are noughts (cyphers) in the divisor.

Mark off also the noughts (cyphers) in the divisor.

The remaining figures then of the dividend are divided by the remaining number of the divisor.

Example. Divide 2469204 by 20.

$$20)\underline{2469204}$$
$$123460\text{–}4\text{–}\tfrac{4}{20}$$

Arrange the divisor 20 and dividend 2469204 in the proper manner, then mark off from the right of the dividend, 2469204, as many figures as there are cyphers in the divisor 20, in which case there will be one figure marked off, because there is one cypher in the divisor.

Having done this, as shown in the examples, the remaining figures, 246920, of the dividend are divided by the remaining number 2 of the divisor, the cypher being marked off, by which operation the quotient, 123460–4, is obtained.

The figure or figures which are marked off in the dividend are in all cases a remainder.

EXAMPLE. Divide 129876347 by 1200.

$$1200\overline{)129876347}$$
$$108230\text{–}347\text{–}\tfrac{347}{1200}$$

After arranging the numbers to be divided one by the other as before, mark off from the right of the dividend as many figures as there are cyphers in the divisor, which cyphers are also marked off. The dividend then becomes 1298763 and the divisor 12, and by dividing we obtain the quotient 108230, with a remainder of 3.

In all cases where there is a remainder, place it in the quotient before the figures of the dividend, which are cut off. In which case this remainder 3 is placed before the figures 47 of the dividend which were cut off, making a remainder of 347, or $\frac{347}{1200}$ as shown.

EXAMPLES FOR EXERCISE

1.	4023 by 5	7.	2045768 by 9
2.	168265 by 4	8.	204050 by 50
3.	8246 by 5	9.	364226734 by 2400
4.	523412 by 6	10.	92643266 by 11
5.	642139 by 7	11.	14465472 by 12
6.	904656 by 8		

When dividing by any number exceeding 12, the operation is performed by a process called "Long Division," and when arranging the numbers to be divided one by the other, by the process of long division, set down the divisor and dividend as in short division, and on the right of the dividend place the quotient.

The dividend and quotient are separated by a curved

line similar to the curved line placed between the divisor and dividend.

Hence the numbers in long division are arranged as follows:

Divisor) Dividend (Quotient

which shows the quotient placed on the right of the dividend.

When dividing a number which is greater than 12 into another number, inquire the number of times the divisor is contained in the least number of figures on the left of the dividend.

Place the figure obtained by the operation in the quotient.

Multiply the figures of the divisor by the quotient figure and place the product under those figures of the dividend in which the divisor operated.

Example. Divide 26 by 13.

Arrange the divisor, dividend, and quotient places as follows:

```
           Dividend
Divisor  13)26(2  Quotient
             26
             --
             00
```

Proceed then to divide the dividend 26 by the divisor 13, saying 13 into 26 goes 2 times.

Place the figure 2 obtained, in the quotient, which is on the right of the dividend.

Then multiply the figures 13 of the divisor by the quotient figure 2. First multiply the figure 3 of the divisor by the quotient figure 2, saying 2 times 3 are 6, which place underneath the figure 6 of the dividend.

Then multiply the next figure 1 of the divisor by the

quotient figure 2, saying 2 times 1 are 2, which place underneath the figure 2 of the dividend.

Draw underneath the product 26 obtained by the multiplication, a horizontal line thus (—)

Subtract the product 26 from the dividend 26 and the division is completed. Showing that 13 is contained in 26 2 times.

Example. Divide 75 by 15.

Arrange the divisor, dividend, and quotient as before.

$$\begin{array}{r} 15)75(5 \\ \underline{75} \\ 00 \end{array}$$

Proceed then to divide the dividend 75 by the divisor 15, saying 15 into 75 goes 5 times. Place the figure 5 in the quotient.

Then multiply the two figures 15 of the divisor by the quotient figure 5, saying 5 times 5 are 25.

Place the right-hand figure 5 of this product 25 under the figure 5 of the dividend and add the left-hand figure 2 of the product to the product of the figure 1 when multiplied by the quotient figure 5, saying 5 times 1 are 5 and 2 are 7.

Place the product figure 7 under the dividend figure 7.

We have now obtained the product 75, which is placed, as explained, under the figures 75 of the dividend.

Proceed then to subtract, saying 5 from 5 leaves 0. Then 7 from 7 leaves 0, and the division is completed.

Examples for Exercise

$$\begin{array}{r} 14)56(4 \\ \underline{56} \\ 00 \end{array} \qquad \begin{array}{r} 13)39(3 \\ \underline{39} \\ 00 \end{array} \qquad \begin{array}{r} 15)60(4 \\ \underline{60} \\ 00 \end{array} \qquad \begin{array}{r} 16)80(5 \\ \underline{80} \\ 00 \end{array}$$

$$\begin{array}{r} 17)34(2 \\ \underline{34} \\ 00 \end{array} \qquad \begin{array}{r} 18)72(4 \\ \underline{72} \\ 00 \end{array}$$

PROCESS. When there is a remainder after subtracting the product, which is obtained by multiplying the divisor by the quotient figure, place the remainder in the quotient and underneath it a short horizontal line, underneath which place the divisor, as in short division.

EXAMPLE. Divide 53 by 13.

Arrange the numbers as before.

$$\begin{array}{r} 13)53(4\tfrac{1}{13} \\ \underline{52} \\ 1 \end{array}$$

Then divide the dividend 53 by the divisor 13, saying 13 is contained in 53 4 times.

Place the figure 4 obtained in the quotient.

Now multiply the divisor 13 by the quotient figure 4, placing the product obtained by the operation underneath the figure 53 of the dividend in which the divisor 13 operated.

Proceed now by subtracting the product 52 from the dividend 53, saying 2 from 3 leaves 1 (remainder) and 5 from 5 leaves nothing. Place the figure 1 (remainder) in the quotient, with the divisor underneath it as shown in the example.

EXAMPLE. Divide 69 by 14.

Arrange the numbers as before.

$$\begin{array}{r} 14)69(4\tfrac{13}{14} \\ \underline{56} \\ 13 \end{array}$$

Inquire the number of times 14, the divisor, is contained in 69, the dividend, saying 14 into 69 goes 4 times.

Place the 4 obtained in the quotient and use it as a multiplier, with the divisor 14 as the multiplicand, by which operation 56 is obtained, which is placed, as shown, underneath the figure of the dividend in which the divisor 14 operated.

Proceed now to subtract, saying 6 from 9 leaves 3 and 5 from 6 leaves 1.

By the subtraction we have 13 (remainder), which place in the quotient with the divisor 14 underneath it, as shown, and the division is finished.

Examples for Practice

14)38($2\frac{10}{14}$	14)58($4\frac{2}{14}$	26)94($3\frac{16}{26}$	572)983($1\frac{411}{572}$
28	56	78	572
10	2	16	411

Process. When there are more figures in the dividend than there are in the product to be subtracted from it, we place on the right of the number obtained by the subtraction the figure next to the figure or group of figures in which the divisor operated. The number thus formed is the dividend in which the divisor operates.

Example. Divide 9424 by 38.

Arrange the divisor and dividend as before.

```
38)9424(248
   76
   ---
   182
   152
   ---
    304
    304
    ---
```

Then inquire the number of times the divisor 38 is contained in the 94, the two left-hand figures of the dividend, and finding it is 2 times, place the 2 in the quotient.

Now multiply the divisor 38 by the quotient figure 2, and subtract the product 76 obtained by the multiplication from dividend figures 94, and to the right of the remainder 18 bring down the next figure 2 of the dividend, making 182.

The number 182 thus formed is the dividend in which the divisor now operates.

Proceed, inquiring how many times 38 is contained in 138, finding it to be 4 times.

The 4 is placed in the quotient. Now multiply the divisor 38 by 4 and subtract the product 152, which is obtained, from 182, and to the right of the remainder 30 bring down the next figure 4 of the dividend. The number 304 thus formed is the dividend in which the divisor next operates, in which case proceed, saying 38 is contained in 304 8 times.

Place the 8 in the quotient and multiply the divisor 38 by it and subtract, as before, the product obtained from the dividend [304].

In which case the division is finished.

EXAMPLE. Divide 14894 by 52.

Arrange the divisor, dividend, and quotient as before.

$$
\begin{array}{r}
52)14894(286\tfrac{22}{52} \\
\underline{104} \\
449 \\
\underline{416} \\
334 \\
\underline{312} \\
22
\end{array}
$$

Proceed to divide, inquiring how many times the divisor 52 is contained in the least number of figures in the left of the dividend.

It is found that 52, the divisor, is contained in 148 2 times.

Place the 2 in the quotient, multiply the divisor by it, and place the product, 104, obtained by the operation underneath the figures 148 of the dividend.

Subtract the product 104 from the dividend figures 148; by so doing we get a remainder of 44, on the right of which place the figure 9 of the dividend.

The number 449 thus formed is the dividend in which the divisor now operates.

Proceed, inquiring the number of times the divisor 52 is contained in 449, and finding it to be 8 times, place the 8 in the quotient, multiply the divisor 52 by it and subtract the product 416, obtained by the operation, from the dividend 449; by so doing we have a remainder of 33, on the right of which we place the next figure 4 of the dividend. The number 334 thus formed is now divided.

In 334, 52 is contained 6 times. Place the 6 in the quotient, multiply the divisor 52 by it, and subtract the product 312, obtained by the operation, from the dividend 334.

By the subtraction there is a remainder of 22, which place in the quotient with the divisor 52 underneath it, as shown.

Examples for Practice

$67)89726(1339\frac{13}{67}$
67
227
201
262
201
616
603
13

$223)6994234(31364\frac{62}{223}$
669
304
223
812
669
1433
1338
954
892
62

25)7284600(291384
50
228
225
34
25
96
75
210
200
100
100

$7645)726981(95\frac{706}{7645}$
68805
38931
38225
706

Process. When there are less figures in the product obtained by multiplying the divisor by a quotient figure than there are in the group of figures in which the divisor

operates, in all cases place the right-hand figure of the product directly underneath the right-hand figure of the group of figures in which the divisor operates.

For instance, divide 1256 by 85.

Arrange the divisor 85, dividend 1256, and quotient as before.

$$
\begin{array}{r}
85)1256(14\frac{66}{85} \\
\underline{85}\phantom{6(14\frac{66}{85}} \\
406\phantom{(14\frac{66}{85}} \\
\underline{340}\phantom{(14\frac{66}{85}} \\
66\phantom{(14\frac{66}{85}}
\end{array}
$$

It is seen here that the two figures 12 on the right of the dividend will not contain the divisor 85, so we inquire the number of times the divisor 85 is contained in the group of three figures on the left of the dividend.

Finding that it is contained in 125 1 time, place the 1 in the quotient, multiply the divisor by it and set the product underneath that group of figures, 125, in which the divisor 85 operates, remembering to place the right-hand figure 5 of the product 85 underneath the right-hand figure 5 of the group of figures in which the divisor operates.

Now subtract the product 85 from the dividend 125, by which operation we get 40; bring down the figure 6 of the dividend forming the number 406, into which the divisor goes 4 times.

Place the 4 in the quotient, multiply the divisor by it, and subtract the product 340, obtained by the operation, from the dividend 406, by doing which we get a remainder of 66, which place as shown in the quotient, and the division is completed.

Example. Divide 20678 by 98.

```
98)20678(211
   196
   ---
    107
     98
     --
      98
      98
      --
```

Having arranged the divisor, dividend, and quotient places as before, inquire the number of times 98, the divisor, is contained in 206, the three left-hand figures of the dividend, and finding it to be 2 times, we place the 2 in the quotient, multiply the divisor 98 by it and subtract the product (196), obtained by the multiplication, from the group of figures 206, and to the right of the remainder 10, obtained by the subtraction, place 7, which is the figure next of the dividend to the group of figures in which the divisor operates, making 107.

We next inquire the number of times 98 is contained in 107 and, finding it to be 1 time, place the 1 in the quotient, then multiply and subtract as before.

Note that the product 98 contains less figures than the group of figures which is divided, in which case, as before stated, the right-hand figure of the product is placed underneath the right-hand figure of the group of figures which form the dividend, so the 8 of the product is placed under the 7 of the dividend. By subtracting the product 98 from 107 there is a remainder of 9, on the right of which place the figure 8, the last figure of the dividend 20678, and proceed as before, saying 98, the divisor, goes into 98, the dividend, in which it operates 1 time. Place the 1 in the quotient and multiply the divisor 98 by it. After finding the product, no remainder is left.

Examples for Practice

$$
\begin{array}{r}
89)46386(521\tfrac{17}{89} \\
445 \\
\hline
188 \\
178 \\
\hline
106 \\
89 \\
\hline
17
\end{array}
\qquad\qquad
\begin{array}{r}
596)131040(219\tfrac{516}{596} \\
1192 \\
\hline
1184 \\
596 \\
\hline
5880 \\
5364 \\
\hline
516
\end{array}
$$

It often happens, when a figure is taken from the dividend and placed on the right of the partial dividend, the number thus formed will not contain the divisor.

When such is the case, place a cypher in the quotient and bring down another figure from the dividend, which place on the right of the partial dividend, and so on till the partial dividend is large enough to contain the divisor.

Example. Divide 7828 by 76.

$$
\begin{array}{r}
76)7828(103 \\
76 \\
\hline
228 \\
228 \\
\hline
\end{array}
$$

Having arranged the divisor, dividend, and quotient places, inquire how many times 76 is contained in the figures 78 on the left of the dividend and, finding it to be 1 time, place the 1 in the quotient, multiply the divisor 76 by it, and subtract the product 76, obtained by the operation, from the 78, and to the right of the remainder 2 place 2, the next figure of the dividend,

making 22. It is seen that 22 will not contain the divisor 76, so we place a cypher (0) in the quotient, and place on the right of the 22 the next figure 8 of the dividend. By so doing we have a partial dividend, 228.

Inquire now how many times the divisor 76 is contained in the number 228 thus formed and, finding it to be 3 times, place the 3 in the quotient, multiply the divisor 76 by it, and subtract the product 228, obtained by the operation, from the partial dividend 228. By the subtraction there is no remainder.

EXAMPLE. Divide 1197965 by 597.

$$
\begin{array}{r@{}l}
597)\,1197965\,(& 2006\tfrac{383}{597} \\
\underline{1194} & \\
3965 & \\
\underline{3582} & \\
383 &
\end{array}
$$

Inquire the number of times the divisor 597 is contained in the least number of figures on the left of the dividend and, finding it to be contained in the figures 1197 2 times, place the 2 in the quotient, multiply the divisor 597 by it; subtract the product, 1194, obtained from the dividend figures 1197. By the subtraction we have 3 left, on the right of which place the next figure 9 of the dividend.

The number 39 thus formed will not contain the divisor, so we place a cypher (0) in the quotient, and place on the right of the 39 the next figure 6 of the dividend, making 396. Again we have a number which will not contain the divisor, so again place a cypher (0) in the quotient.

Then bring down the next figure 5 of the dividend,

placing it on the right of the figures 396, making 3965 as a partial dividend. Then the divisor 597 is seen to be contained in 3965, the number thus formed, 6 times. Place the 6 in the quotient, multiply the divisor by it, and subtract the product from the partial dividend 3965.

Examples for Exercise

Divide:

1. 76298764833 by 9.
2. 120047629817 by 20.
3. 9876543216 by 48.
4. 3247617219 by 63.
5. 7141072617 by 41.
6. 329817228 by 107.
7. 24769876237 by 987.
8. 2610014723 by 2406.

It will be noticed that three arithmetical rules are required to perform operations in long division, namely: division, multiplication, and subtraction.

TABLES

(Tables of weights and measures used by mechanics.)

Capacity

4 gills make 1 pint
2 pints make 1 quart.
4 quarts make 1 gallon.
2 gallons make 1 peck.
4 pecks make 1 bushel.
8 bushels make 1 quarter.
5 quarters make 1 load.

The long ton of 2240 avoirdupois pounds is used at custom houses, and in weighing coal at the mines.

Length

12 inches make 1 foot.
3 feet make 1 yard.
6 feet make 1 fathom.
5½ yards make 1 rood, pole, or perch.
40 poles make 1 furlong.
8 furlongs make 1 mile.
3 miles make 1 league.
5280 feet or 1760 yards make 1 geographical mile.
6080 feet make 1 nautical mile.

Surface

144 square inches make 1 square foot.
9 square feet make 1 square yard.
30¼ square yards make 1 square rood, pole, or perch
40 perches make 1 rood.
4 roods make 1 acre.
640 acres make 1 square mile.

Solidity

1728 cubic inches make 1 cubic foot.
27 cubic feet make 1 cubic yard.

Dimensions

12 inches make 1 foot.
144 square inches make 1 square foot.
1728 cubic inches make 1 cubic foot.
5280 feet make 1 geographical mile
6080 feet make 1 nautical mile or knot.

Time

60 seconds (sec.) make 1 minute (mi.).
60 minutes make 1 hour (h.).

24 hours make 1 day (d.).
365 days make 1 common year (y.).
366 days make 1 leap year (l. y.).
7 days make 1 week (wk.).
12 calendar months (mo.) make 1 year.
100 years make 1 century.

The "Civil Day" begins at 12 o'clock midnight.

Weights

Troy

24 grains (gr.) are 1 pennyweight.
20 pennyweight are 1 ounce (oz.).
12 ounces are 1 pound (lb.).

Avoirdupois

16 ounces (oz.) are 1 pound (lb.).
100 pounds are 1 cental (ctl.).
2000 pounds are 1 ton (T.).

A pound avoirdupois is equal to 7000 grains, and a pound troy is equal to 5760 grains, so that 144 pounds avoirdupois are equal to 175 pounds troy.

Circular Measure

60 seconds (″) are 1 minute (′).
60 minutes are 1 degree (°).
360 degrees are 1 circumference (cir.).

The circumference of a circle is supposed to be divided into 360 equal parts, called degrees.

A degree is therefore $\frac{1}{360}$ of the circumference of a circle.

A quadrant is a fourth of a circumference, or an arc of 90 degrees.

A degree is divided into 60 minutes expressed by sign (′) and each minute is divided into 60 seconds expressed by sign (″), so that the circumference of any circle contains 21,600 minutes, 1,296,000 seconds.

Wood Measure

16 cubic feet are 1 cord foot (cd. ft.).
8 cord feet or 128 cubic feet are 1 cord (cd.).

Weights of Water

1 gallon of fresh water weighs 10 pounds.

1 gallon of sea water (specific gravity of 1029) weighs $10\frac{1}{4}$ pounds.

1 gallon equals $\frac{16}{100}$ (.16) of a cubic foot, or 1 cubic foot equals $6\frac{1}{4}$ gallons.

1 cubic foot of fresh water weighs $62\frac{1}{2}$ pounds, equal to 1000 ounces.

1 cubic foot of sea water weighs 64 pounds.

35 cubic feet of sea water weigh 1 ton.

35.84 ($35\frac{84}{100}$) cubic feet of fresh water weigh 1 ton.

Weights of Metals

Wrought iron 3.6 cubic inches weigh 1 pound; or 1 cubic inch equals .2778 of a pound.

Cast iron 3.9 cubic inches weigh 1 pound; or 1 cubic inch equals .257 of a pound.

Soft steel 3.55 cubic inches weigh 1 pound; or 1 cubic inch equals .2814 of a pound.

Brass or gun metal 3.3 cubic inches weigh 1 pound; or 1 cubic inch equals .3 of a pound.

REDUCTION

Reduction is the process of changing numbers from one denomination to another denomination of the same general kind without altering their values.

By denomination is meant name.

Thus 36 feet is a denomination.

Also in 3 days, 7 hours, 50 minutes, there are three denominations (days, hours, and minutes).

It is possible by the process of reduction to change number of a higher denomination to a lower denomination without altering their value.

For example: 3 feet may be reduced to 36 inches.

Here feet is a higher denomination than inches, because it takes a certain number of inches to make a foot, But by reducing 3 feet to 36 inches the value is not changed, as 3 feet and 36 inches represent the same length.

It is also possible by the process of reduction to change numbers of a lower denomination to numbers of a higher denomination and not alter their values.

Inches may be reduced to feet, for instance.

Thus 36 inches reduced to feet is 3 feet.

Here inches, the lower denomination, is reduced to feet, the higher, but the values are unchanged, as 36 inches and 3 feet, as stated before, are equal.

Process. When reducing a higher to lower denominations, multiply the higher denomination which is to be reduced by the number of units it takes of the next lower denomination to equal one of that higher denomination, and then to the product add the given numbers, if any, of the smaller denomination.

Example. Reduce 27 pounds to ounces.

As the next lower denomination to pounds is ounces,

we will multiply the 27 pounds by the number of units it takes of that denomination (ounces) to make 1 pound.

Then, as 16 ounces make 1 pound, 27 pounds multiplied by 16 ounces will give us the number of ounces contained in 27 pounds. Thus:

$$\begin{array}{r l}
27 & \\
\underline{16} & \\
162 & \\
\underline{27} & \\
432 & \text{oz.} \quad \textit{Ans.}
\end{array}$$

Example. How many ounces are there in 25 lb. 7 oz.?

As 16 ounces make a pound, multiply the 25 pounds by 16 as follows:

$$\begin{array}{r l}
25 & \text{lb. 7 oz.} \\
\underline{16} & \\
150 & \\
\underline{25} & \\
400 & \\
\underline{7} & \\
407 & \text{oz.}
\end{array}$$

The product of which is 400 ounces, and to the product add the 7 ounces, making 407 ounces.

Hence in 25 lb. and 7 oz. there are 407 ounces.

Example. How many grains are there in 4 pennyweight (dwt.) troy?

Now 24 grains make a pennyweight, therefore multiply the 4 by 24 as follows:

$$\begin{array}{r l}
4 & \\
\underline{24} & \\
96 & \text{gr.} \quad \textit{Ans.}
\end{array}$$

Example. How many pennyweights are there in 5 ounces (troy)?

20 pennyweights make an ounce, therefore to find the number of pennyweights in 5 ounces, multiply the 5 by 20 as follows:

$$\begin{array}{r} 5 \\ \underline{20} \\ 100 \text{ dwt.} \quad \textit{Ans.} \end{array}$$

Example. How many ounces are there in 16 pounds (troy)?

Now 12 ounces make a pound (troy), therefore multiply the 16 by 12 as shown.

$$\begin{array}{rl} 16 & \text{lb.} \\ \underline{12} & \text{oz.} \\ 192 & \text{oz.} \quad \textit{Ans.} \end{array}$$

Example. How many grains are there in 32 lb. 10 oz. 15 dwt. 7 gr. (troy)?

$$\begin{array}{rl} 32 & \text{lb. 10 oz. 15 dwt. 7 gr.} \\ \underline{12} & \\ 394 & \text{oz.} \\ \underline{20} & \\ 7880 & \\ \underline{15} & \\ 7895 & \text{dwt.} \\ \underline{24} & \\ 31580 & \\ \underline{15790} & \\ 189487 & \text{gr.} \quad \textit{Ans.} \end{array}$$

Bring the 32 pounds to ounces by multiplying by 12 (12 ounces equals a pound troy).

To the product 384 add the 10 ounces, making 394 ounces.

Now bring the 394 ounces to pennyweights by multiplying by 20 (there being 20 pennyweights in one ounce).

To the product 7880 add the 15 pennyweights, making 7895 pennyweights.

Proceed now to convert the 7895 pennyweights into grains.

A grain equals 24 pennyweights, therefore multiply 7895 by 24 and to the product add the 7 grains.

And, as shown, in 32 lb. 10 oz. 15 dwt. 7 gr. there are 189487 grains.

Example. Reduce 3 yd. 2 ft. 9 in. to inches.

Bring the yards to feet, then bring the feet to inches as follows:

$$\begin{array}{r l}
3 & \text{yd. 2 ft. 9 in.} \\
\underline{3} & \\
11 & \text{ft.} \\
\underline{12} & \\
141 & \text{in.} \quad \textit{Ans.}
\end{array}$$

As shown, we bring the 3 yards to feet by multiplying by 3, there being 3 feet in one yard, add 2 feet to the product, making 11 feet. We then bring the 11 feet to inches by multiplying by 12, because there are 12 inches in one foot, and to the product add the 9 inches, and, as shown, in 3 yd. 2 ft. 9 in. there are 141 inches.

Process. When reducing lower to higher denominations, divide first the given number by the number of units it takes of that denomination to equal one of the next larger, and reserve the remainder, if any, and divide next the quotient and so proceed until the re-

quired denomination is reached. The last quotient and the several remainders, if any, will be the number sought.

EXAMPLE. How many pounds are there in 407 ounces? In other words, reduce 407 ounces to pounds.

Divide first the given number, 407 ounces, by that number of units it takes of that denomination of ounces to make one of the next larger denomination. The next larger denomination is pounds, and as it takes 16 ounces to make one pound, we divide 407 by 16. Thus:

$$\begin{array}{r} 16\underline{)407} \\ 25\text{–}7 \end{array}$$

Dividing, then, the 407 ounces by 16 reduces it to 25 pounds, and the remainder 7 is ounces.

The above answer then reads 25 lb. 7 oz.

EXAMPLE. How many pounds are there in 179 ounces?

Here, as before, to bring the 179 ounces to pounds, divide by 16, because there are 16 ounces in a pound avoirdupois, and if there is a remainder it is called ounces, as follows:

$$\begin{array}{r} 16\underline{)179} \\ 11\text{–}3 \end{array} \quad \textit{Ans. } 11 \text{ lb. } 3 \text{ oz.}$$

EXAMPLE. How many yards in 141 inches?

First bring the 141 inches to feet by dividing by 12, as follows:

$$\begin{array}{r} 12\underline{)141} \\ 3\underline{)11\text{–}9 \text{ in.}} \\ 3\text{–}2\text{–}9 \end{array}$$

By so doing we have a quotient of 11 and 9 over, which are inches. Next bring the 11 feet to yards by dividing by 3, because 3 feet is one yard, as shown. And we obtain the quotient of 3 yards 2 feet.

Hence in full the answer is 3 ft. 2 yd. 9 in.

EXAMPLE. How many pounds are there in 189487 grains?

```
24)189487
2.0) 7895-7 gr.
12)  394.15 dwt.
      32.10 oz.
```

Ans. 32 lb. 10 oz. 15 dwt. 7 gr.

FRACTIONS

The term fraction is derived from the Latin word *frango*, which means to break or separate into parts.

A fraction, then, means a part of a whole thing or a part of any number. And by the use of fractions we are enabled to perform arithmetical operations where numbers less than *whole* numbers are employed. There are two kinds of fractions, called vulgar fractions and decimal fractions, each of which are represented differently. This chapter pertains to vulgar or common fractions only.

A vulgar or common fraction is always represented by not less than two numbers, one of which is placed over the other, having a short horizontal or diagonal line between them. Thus:

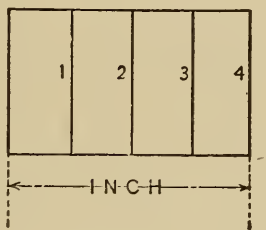
$$\frac{3}{8} \text{ or } 3/8$$

A horizontal line is — and a diagonal line is / .

That number which is above the line is called the numerator, and the number underneath the line is called the denominator. Thus in the above fraction 3 is the numerator and 8 is the denominator. The denominator always denotes the number of equal parts there are in a *whole thing*. The numerator always denotes the num-

ber of those equal parts we have. Thus in the fraction $\frac{3}{8}$, the 8 tells us the whole thing has been divided into eight equal parts, and the 3 tells us that there are three of those equal parts represented.

For instance, take some specific length, say one inch, and divide it into a number of equal lengths, say four. Thus:



If it is required now to specify in figures a number that will represent a length equal to one of the divisions, we would represent it thus, $\frac{1}{4}$ inches. The denominator 4 would show that the inch (the whole thing) is divided into four equal parts, and the numerator would tell the number of those parts represented. Likewise, $\frac{3}{4}$ inches would represent a dimension equal in length to three of the four equal divisions into which the whole inch is divided. Practically speaking, vulgar fractions are divided into six different classes, named:

1. Proper fractions.
2. Improper fractions.
3. Mixed fractions.
4. Compound fractions.
5. Simple fractions.
6. Complex fractions.

First. A Proper fraction is a fraction whose numerator is less than its denominator.

As $\frac{3}{4}$ or $\frac{1}{2}$ or $\frac{5}{8}$

Second. An Improper fraction is a fraction whose numerator is equal to or greater than its denominator.

As $\frac{3}{3}$ or $\frac{9}{3}$ or $\frac{6}{2}$ or $\frac{5}{3}$

Third. A Mixed number is a whole number with a fraction.

As $8\frac{7}{8}$ or $5\frac{3}{4}$ or $6\frac{1}{2}$

Fourth. A Compound fraction is a fraction of a fraction.

As $\frac{1}{2}$ of $\frac{3}{4}$, or $\frac{3}{4}$ of $\frac{5}{8}$, or $\frac{1}{2}$ of $\frac{1}{4}$

Fifth. A Simple fraction has but one numerator and one denominator, and may be either improper or proper.

As $\frac{3}{4}$ or $\frac{3}{2}$ or $\frac{3}{5}$ or $\frac{5}{3}$

Sixth. A Complex fraction is a fraction which has either a compound fraction, a mixed number, a whole number, or a simple fraction, for either its numerator or denominator, or both.

$$\text{As } \frac{\frac{3}{4}}{\frac{7}{8}},$$

an example of a complex fraction having simple fractions for numerator and denominator;

$$\text{or } \frac{6}{3\frac{3}{4}},$$

example of complex fraction having whole number for numerator and mixed number for denominator;

$$\text{or } \frac{4\frac{1}{2}}{5\frac{3}{4}},$$

example of complex fraction having mixed numbers for numerator and denominator.

REDUCTION OF FRACTIONS

Reduction of fractions is the process of changing fractional terms without altering their values. The "terms" of a fraction means its numerator and denominator.

To reduce a fraction to its lowest terms, divide the numerator and denominator by any number that will divide them both without a remainder.

EXAMPLE. Reduce $\frac{8}{12}$ to its lowest terms. Thus:

$$4)\frac{8}{12} = \frac{2}{3}$$

Here 4 will divide both numerator 8 and denominator 12 without a remainder. 4 goes into 8 two times and into 12 three times. Hence $\frac{2}{3}$ is equal to $\frac{8}{12}$ In other words, $\frac{8}{12}$ of an inch is the same part of an inch (or length) as $\frac{2}{3}$ of an inch is, or $\frac{2}{3}$ of an apple would represent a piece of an apple the same size as $\frac{8}{12}$ of the same apple. Therefore, by bringing the fraction $\frac{8}{12}$ to its lowest terms, $\frac{2}{3}$, the value of the fraction, has not been altered. The terms of the fraction were changed only.

Reduction of fractions, then, is performed by dividing the numerator and denominator by any number that will divide them both without a remainder, and the successive results of the division are divided by any number that will divide them both without a remainder, until the operation of dividing can be carried no further.

EXAMPLE. Reduce $\frac{24}{72}$ to its lowest terms.

$$8)\frac{24}{72} = \frac{3}{9} = \frac{1}{3}$$

Here the number 8 will divide the numerator and denominator without a remainder, and by the division is obtained $\frac{3}{9}$. We next divide this result by 3, because 3 will divide both 3 and 9 without any remainder, and obtain $\frac{1}{3}$, which cannot be further divided; therefore, $\frac{1}{3}$ is the fraction $\frac{24}{72}$ reduced to its lowest terms, and both fractions represent the same value.

Example. Reduce $\frac{1728}{13824}$ to its lowest terms.

First divide the numerator and denominator by 12, and by the division the terms become $\frac{144}{1152}$. Then divide again by 12 and the terms $\frac{144}{1152}$ become $\frac{12}{96}$. 12 will again divide them and it becomes $\frac{1}{8}$, which is the lowest term. Consequently, $\frac{1}{8}$ of an inch is the same length as $\frac{1728}{13824}$ of an inch.

Examples for Exercise

Reduce $\frac{6}{12}$ to its lowest terms.	*Ans.* $\frac{1}{2}$
Reduce $\frac{5}{30}$ to its lowest terms.	*Ans.* $\frac{1}{6}$
Reduce $\frac{14}{21}$ to its lowest terms.	*Ans.* $\frac{2}{3}$
Reduce $\frac{12}{96}$ to its lowest terms.	*Ans.* $\frac{1}{8}$
Reduce $\frac{18}{54}$ to its lowest terms.	*Ans.* $\frac{1}{3}$.
Reduce $\frac{144}{1728}$ to its lowest terms.	*Ans.* $\frac{1}{12}$.
Reduce $\frac{236}{417}$ to its lowest terms.	*Ans.* $\frac{236}{417}$.

To reduce a fraction of any denominator to a fraction having a greater denominator, that is, to bring a fraction to its largest terms, which is the reverse of the last rule, see how many times the denominator of the fraction in sight will divide into the larger denominator to which you are to bring it.

Example. Bring $\frac{1}{2}$ to a fraction whose denominator is 8.

Proceed by dividing the denominator 2 of the fraction $\frac{1}{2}$ into the greater denominator 8, and multiply the numerator and denominator of the fraction $\frac{1}{2}$ in sight by the quotient obtained by the division. Here 2 goes into 8 four times. Then multiply the numerator and denominator of the fraction $\frac{1}{2}$ by the quotient 4, and by the multiplication is obtained $\frac{4}{8}$.

Multiplying both terms of a fraction by the same number does not change its value, hence,

$$\frac{1}{2} = \frac{4}{8}.$$

That is, $\frac{1}{2}$ of an inch would be equal to $\frac{4}{8}$ of an inch.

Example. Bring $\frac{2}{3}$ to a fraction whose denominator is 15.

Here 3 goes into 15 five times, then $\frac{2}{3}$ becomes $\frac{10}{15}$.

Examples for Exercise

Bring $\frac{2}{3}$ to a fraction whose denominator is 12. *Ans.* $\frac{8}{12}$.
Bring $\frac{3}{4}$ to a fraction whose denominator is 16. *Ans.* $\frac{12}{16}$.
Bring $\frac{3}{5}$ to a fraction whose denominator is 20. *Ans.* $\frac{12}{20}$.
Bring $\frac{1}{2}$ to a fraction whose denominator is 8. *Ans.* $\frac{4}{8}$.

When bringing a fraction to its largest terms, as in the above examples, the denominator of the fraction whose terms are to be changed must divide into the denominator to which it is to be changed without a remainder.

To reduce a mixed number to an improper fraction, multiply the whole number by the denominator of the fraction, and to the product add the numerator, and place their sum over the denominator of the fraction.

Example. Reduce $6\frac{7}{8}$ to an improper fraction.

Multiply the whole number 6 by the denominator 8 of the fraction, and add to the product obtained by the multiplication the numerator 7, saying 8 times 6 are 48 and 7 are 55. Place the sum 55 thus obtained over the denominator 8 of the fraction, as follows:

$$\frac{55}{8}$$

Then $\frac{55}{8}$ represents the mixed number $6\frac{7}{8}$ when reduced

to an improper fraction, and it shows that there are contained in $6\frac{7}{8}$, 55 eighths. That is, there would be contained in $6\frac{7}{8}$ inches 55 eighths of an inch.

For instance, in one inch there are 8 eights, therefore in 6 inches there are just six times as many eighths, which would be 48 eighths, to which add seven more eighths and you have 55 eighths.

Examples for Exercise

Reduce $4\frac{3}{4}$ to an improper fraction. *Ans.* $\frac{19}{4}$
Reduce $5\frac{7}{8}$ to an improper fraction. *Ans.* $\frac{47}{8}$.
Reduce $6\frac{2}{3}$ to an improper fraction. *Ans.* $\frac{20}{3}$.
Reduce $10\frac{3}{5}$ to an improper fraction. *Ans.* $\frac{53}{5}$.
Reduce $67\frac{4}{6}$ to an improper fraction. *Ans.* $\frac{406}{6}$.

To reduce an improper fraction to a whole or mixed number, divide the numerator by the denominator, and if there is a remainder, place it over the denominator at the right of the whole number obtained by the division.

Example. Change $\frac{24}{16}$ to a mixed number.

Divide the numerator 24 by the denominator 16 as follows, and place the remainder $\frac{1}{2}$ on the right of the whole number 1, obtained by the division.

$$\begin{array}{r} 16)24(1\frac{1}{2} \\ \underline{16} \\ \dfrac{\cancel{8}}{\cancel{16}} = \frac{1}{2} \end{array}$$

Examples for Exercise

Reduce $\frac{12}{4}$ to a whole number. *Ans.* 3.
Change $\frac{89}{6}$ to a mixed number. *Ans.* $14\frac{5}{6}$.
Reduce $\frac{45}{3}$ to a whole number. *Ans.* 15.
Change $\frac{673}{14}$ to a mixed number. *Ans.* $48\frac{1}{14}$.

To reduce a compound fraction to a single fraction:

EXAMPLE. Reduce $\frac{3}{4}$ of $\frac{7}{8}$ to a single fraction.

Multiply all the numerators together for the new numerator (that is, for the numerator of the single fraction), and all the denominators together for the new denominator; then, if necessary, reduce the fraction obtained to its lowest terms. Bear in mind that the sign $\times$ is read "multiplied by" and means that the number before it is multiplied by the number after it.

Proceed now to reduce the above compound fraction to a simple, or single, fraction, as follows:

$$\frac{3}{4} \times \frac{7}{8} = \frac{21}{32}. \quad \textit{Ans.}$$

As shown, the numerator 3 and 7 are multiplied together for the new numerator, which is 21, and the denominators 4 and 8 are multiplied together for the new denominator, which is 32. We then have the fraction $\frac{21}{32}$.

EXAMPLE. Reduce $\frac{2}{3}$ of $\frac{1}{5}$ of $\frac{7}{16}$ to a single fraction.

As before, multiply all the numerators together for the new numerator, and all the denominators for the new denominator, and, if necessary, reduce the fraction obtained by the multiplication to its lowest terms, as follows:

$$\frac{2}{3} \times \frac{1}{5} \times \frac{7}{16} = \frac{\cancel{14}}{\cancel{240}} = \frac{7}{120} \quad \textit{Ans.}$$

By multiplying all numerators together we get a new numerator, 14, and by multiplying the denominators together we get a new denominator, 240, both of which may be divided by 2 without a remainder, as shown. By a process of canceling we can also reduce a compound fraction to a single fraction.

Rules for Canceling:

Any numerator can be divided into any denominator, provided no remainder is left, and any denominator can be divided into any numerator, provided no remainder is left.

Example. Reduce $\frac{3}{4}$ of $\frac{2}{3}$ of $\frac{4}{9}$ to a single fraction. Thus:

$$\frac{\cancel{3}}{\cancel{4}} \text{ of } \frac{2}{\cancel{3}} \text{ of } \frac{\cancel{4}}{9}$$

Here the 3 in the first numerator and the 3 of the second denominator will cancel one into the other; these are therefore left out. Also the 4 of the first denominator cancels with the 4 of the last numerator, and then we have 2 left as a numerator and 9 as a denominator. Thus:

$$\frac{2}{9}$$

Many problems may be considerably shortened by the process of cancellation, as the following example will show.

Example. Reduce $\frac{2}{9}$ of $\frac{3}{8}$ of $\frac{14}{18}$ of $\frac{90}{170}$ to a single fraction. Thus:

$$\frac{\cancel{2}}{\underset{3}{\cancel{9}}} \text{ of } \frac{\cancel{3}}{\underset{\underset{2}{\cancel{4}}}{\cancel{8}}} \text{ of } \frac{\overset{7}{\cancel{14}}}{\cancel{18}} \text{ of } \frac{\overset{\cancel{5}}{\cancel{90}}}{\underset{34}{\cancel{170}}} = \frac{7}{3 \times 2 \times 34} = \frac{7}{204}$$

The process is as follows: The first numerator, 2, will go into 8, the denominator of the second fraction, 4 times; the denominator 18, of the third fraction, will go into the 90, the numerator of the last quantity, 5 times. The numerator 3 of the second fraction will go into the denominator 9 of the first fraction, 3 times. 5 will go into the denominator 170, of the last quantity, 34 times; 2 will go into 4 twice, and into the numerator 14 of the

third fraction, 7 times. And as we cannot find any more figures that can be divided without leaving a remainder, we are at an end and the quantity left must be put into an expression. On examination, we have 7 left in the top row; this is put down at the end as the final numerator. On the bottom we have 3, 2, and 34; these multiplied together give us 204, which is the final denominator.

Any numerator and denominator may be divided by the same number, provided there be no remainder left, and the values obtained by the division are used in the place of the values that were canceled.

EXAMPLES. Reduce $\frac{3}{8}$ of $\frac{20}{31}$ to a single fraction.

Here 8, the denominator of the first fraction, can be divided by 4, and 20, the numerator of the last quantity, can be divided by the same number without leaving any remainder, as shown. Thus:

$$\frac{3}{\underset{2}{\cancel{8}}} \text{ of } \frac{\overset{5}{\cancel{20}}}{31} = \frac{3 \times 5}{2 \times 31} = \frac{15}{62} \quad Ans.$$

EXAMPLE. Reduce $\frac{8}{15}$ of $\frac{5}{32}$ of $\frac{14}{17}$ to a single fraction. Thus:

$$\frac{\cancel{8}}{\underset{3}{\cancel{15}}} \text{ of } \frac{\cancel{5}}{\underset{\underset{2}{\cancel{4}}}{\cancel{32}}} \text{ of } \frac{\overset{7}{\cancel{14}}}{17} = \frac{7}{3 \times 2 \times 17} = \frac{7}{102}$$

EXAMPLES FOR EXERCISE

Reduce to their simplest forms the fractions:

$$\tfrac{1}{2} \text{ of } \tfrac{2}{3} \text{ of } \tfrac{3}{4} \text{ of } \tfrac{4}{5}$$

This can be done by canceling as follows. Thus:

$$\frac{1}{\cancel{2}} \text{ of } \frac{\cancel{2}}{\cancel{3}} \text{ of } \frac{\cancel{3}}{\cancel{4}} \text{ of } \frac{\cancel{4}}{5} = \frac{1}{5} \quad \textit{Ans.}$$

Reduce $\frac{3}{5}$ of $\frac{15}{16}$ of $\frac{4}{9}$ to a single fraction.

$$\frac{3}{\cancel{5}} \text{ of } \frac{\overset{3}{\cancel{15}}}{\underset{4}{\cancel{16}}} \text{ of } \frac{\cancel{4}}{\underset{3}{\cancel{9}}} = \frac{3}{4 \times 3} = \frac{3}{12}$$

Reduce $\frac{5}{7}$ of $\frac{1}{4}$ of $\frac{14}{15}$ to a single fraction. Thus:

$$\frac{\cancel{5}}{\cancel{7}} \text{ of } \frac{1}{\underset{2}{\cancel{4}}} \text{ of } \frac{\overset{2}{\cancel{14}}}{\underset{3}{\cancel{15}}} = \frac{1}{2 \times 3} = \frac{1}{6}$$

Reducing Whole Numbers to Improper Fractions

Placing 1 for a denominator under a whole number reduces the whole number to an improper fraction.

Example. Reduce 7 to an improper fraction.

Place 1 under the whole number 7 and we have an improper fraction, whose numerator is 7 and whose denominator is 1. Thus:

$$\frac{7}{1}$$

All whole numbers in a compound fraction must be converted into an improper fraction before multiplying the numerators together and the denominators together.

Example. What is the value of $\frac{3}{5}$ of $\frac{4}{9}$ of 7.

Notice that the last quantity, 7, is a whole number. It is therefore converted into an improper fraction by placing 1 underneath it for a denominator, as follows:

$$\frac{\cancel{3}}{5} \text{ of } \frac{4}{\underset{3}{\cancel{9}}} \text{ of } \frac{7}{1} = \frac{4 \times 7}{5 \times 3 \times 1} = \frac{28}{15}$$

$$15)28(1\tfrac{13}{15}$$
$$\underline{15}$$
$$13$$

By first canceling and then multiplying the remaining numerators together for a new numerator, and then multiplying the remaining denominators together for the new denominator, we obtain the improper fraction $\frac{28}{15}$, which is reduced to a mixed number. Then, as shown, the value of $\frac{3}{5}$ of $\frac{4}{9}$ of $7 = 1\frac{13}{15}$.

All mixed numbers in a compound fraction must be reduced to an improper fraction before multiplying the numerators together and the denominators together.

EXAMPLE. Find the value of $\frac{3}{5}$ of $\frac{4}{11}$ of $\frac{11}{12}$ of $\frac{12}{23}$ of $5\frac{3}{4}$.

Notice the last value, $5\frac{3}{4}$, is a mixed number, which, when reduced to an improper fraction is $\frac{23}{4}$.

Then we have $\frac{3}{5}$ of $\frac{4}{11}$ of $\frac{11}{12}$ of $\frac{12}{23}$ of $\frac{23}{4}$.

After canceling and multiplying together the remaining numerators for the new numerator, and the remaining denominators for the new denominator, we have, as shown:

$$\frac{3}{5} \text{ of } \frac{\cancel{4}}{\cancel{11}} \text{ of } \frac{\cancel{11}}{\cancel{12}} \text{ of } \frac{\cancel{12}}{\cancel{23}} \text{ of } \frac{\cancel{23}}{\cancel{4}} = \frac{3}{5}$$

EXAMPLES FOR EXERCISE

Reduce $\frac{4}{6}$ of $\frac{8}{10}$ of $\frac{12}{14}$ to single fraction. *Ans.* $\frac{4}{35}$.

Reduce $\frac{7}{8}$ of $\frac{9}{11}$ of 7 to mixed numbers. *Ans.* $4\frac{13}{44}$.

What is $\frac{3}{8}$ of $\frac{5}{11}$ of $\frac{3}{7}$ of $\frac{4}{9}$. *Ans.* $\frac{5}{154}$.

Change to a single fraction $\frac{11}{17}$ of $\frac{1}{2}$ of $\frac{3}{4}$ of $\frac{1}{20}$ of 8. *Ans.* $\frac{33}{340}$.

Find the value of $\frac{2}{3}$ of $\frac{1}{6}$ of $\frac{6}{9}$ of $\frac{9}{11}$ of $\frac{11}{12}$ of $5\frac{3}{4}$. *Ans.* $\frac{23}{72}$.

What is $\frac{3}{4}$ of $2\frac{3}{4}$. *Ans.* $2\frac{1}{16}$.

Reduce $\frac{8}{11}$ of $\frac{22}{35}$ of $\frac{15}{22}$ of $9\frac{5}{8}$ to a whole number. *Ans.* 3.

REDUCTION OF COMPLEX FRACTIONS

PROCESS. Reduce first all whole numbers, if any, and all mixed numbers, if any, to improper fractions, and

then reduce all compound fractions, if any, to single fractions. Then divide the numerator of the complex fraction by the denominator, according to the rule for the division of fractions.

EXAMPLE. Reduce $\frac{\frac{3}{8}}{\frac{3}{4}}$ to a single fraction.

This is an example of a complex fraction having for both terms single fractions. Knowing that the numerator of a fraction is the dividend and the denominator is the divisor, all that will be required to solve the above problem is to divide the numerator $\frac{3}{8}$ by the denominator $\frac{3}{4}$. Thus:

$$\frac{\frac{3}{8}}{\frac{3}{4}} = \frac{3}{8} \div \frac{3}{4} = \frac{3}{8} \times \frac{4}{3} = \frac{12}{24} = \frac{1}{2} \quad \textit{Ans.}$$

EXAMPLE. Reduce $\frac{3}{5\frac{5}{8}}$ to a single fraction. Thus:

$$\frac{3}{5\frac{5}{8}} = \frac{\frac{3}{1}}{\frac{45}{8}} = \frac{3}{1} \div \frac{45}{8} = \frac{3}{1} \times \frac{8}{45} = \frac{24}{45} \quad \textit{Ans.}$$

The above example shows that the whole numbers and mixed numbers were first reduced to improper fractions. We then proceed with the operation as in former example.

EXAMPLE. Reduce $\frac{\frac{3}{7}}{\frac{1}{2} \text{ of } \frac{3}{4}}$ to a single fraction. Thus:

$$\frac{\frac{3}{7}}{\frac{1}{2} \text{ of } \frac{3}{4}} = \frac{\frac{3}{7}}{\frac{3}{8}} = \frac{3}{7} \div \frac{3}{8} = \frac{3}{7} \times \frac{8}{3} = \frac{24}{21} = 1\tfrac{3}{21} = 1\tfrac{1}{7} \quad \textit{Ans.}$$

As shown, the denominator $\frac{1}{2}$ of $\frac{3}{4}$, which is a compound fraction, is first reduced to a single fraction and then we proceed as before.

EXAMPLES FOR EXERCISE

Reduce to single fraction $\frac{\frac{1}{2}}{\frac{3}{4}}$ *Ans.* $\frac{2}{3}$.

Reduce to single fraction $\dfrac{8\frac{1}{2}}{\frac{3}{4}}$ *Ans.* $11\frac{1}{3}$

Reduce to single fraction $\dfrac{3\frac{3}{8}}{2\frac{1}{2}}$ of $\dfrac{\frac{3}{7}}{\frac{5}{6}}$ *Ans.* $\frac{243}{350}$

Following now are the rules, with examples, which govern operations in Addition, Subtraction, Multiplication, and Division of Vulgar Fractions. And note, when performing such operations, that all fractions contained in a problem are first reduced to their simplest form.

Addition of Fractions

Addition of vulgar fractions is the process of adding together two or more fractions, so that their value can be expressed in one sum.

When adding together a number of fractions having the same denominator, add together the several numerators for the new numerator and reduce the fraction obtained in this way to its simplest form.

ARITHMETICAL SIGNS

As the following signs are used in performing operations in fractions, it is necessary that the pupil should understand them.

The sign $+$ is read "plus," and means that the number after it is to be added to the number before it; thus, $5 + 4$ are 9.

The sign $-$ is read "minus," and means that the number after it is to be subtracted from the number before it; thus, $9 - 4$ is 5.

The sign $\times$ is read "multiply by," and means that the number after it is multiplied by the number before it; thus, 7×3 are 21.

The sign $\div$ is read "divide by," and means that

the number before it is to be divided by the number after it; thus, $12 \div 6$ are 2.

The sign $=$ is read "equal to," and means that the quantity after it is of the same value as the quantity before it; thus, $4 + 5 = 9$.

Addition of Fractions

Example. Add together, or find the sum of, $\frac{1}{8}$, $\frac{3}{8}$, and $\frac{5}{8}$.

Here we have three fractions to add together, all having the same denominator, 8. As before stated, the denominator tells us how many equal parts the whole thing has been divided into, and the numerator shows us how many of those parts we have. Therefore, in the example, we have in the first fraction 1 part of the whole thing, and in the second fraction we have 3 parts of the whole thing, and in the third fraction we have five parts of the whole thing. Therefore, it is evident, to find the number of parts contained in the three fractions, we add together the numerators 1, 3, and 5, the sum of which equals 9. The 9 thus obtained is the new numerator, and we have the fraction $\frac{9}{8}$, which, reduced to its simplest terms, equals $1\frac{1}{8}$. Then, as shown, the sum of $\frac{1}{8}$, $\frac{3}{8}$, and $\frac{5}{8}$ equals $\frac{9}{8}$ or $1\frac{1}{8}$.

Example. Add together, or find the sum of,

$$\tfrac{1}{16},\ \tfrac{3}{16},\ \tfrac{5}{16},\ \tfrac{9}{16}, \text{ and } \tfrac{13}{16} = \tfrac{31}{16} \text{ or } 1\tfrac{15}{16} \quad \textit{Ans.}$$

Here you have again a number of fractions to add together, all having the same denominator, and as each of the numerators represents a certain number of parts of the whole thing that is divided into 16 equal parts, it is evident, to get the sum of all the parts represented by the several numerators, these numerators are simply

added together and the sum is written over the common denominator, and the fraction, $\frac{31}{16}$, thus formed, is reduced to its simplest terms and $1\frac{15}{16}$ is the required sum.

Examples for Exercise

Add together $\frac{3}{17}$, $\frac{2}{17}$, $\frac{5}{17}$, $\frac{8}{17}$, $\frac{1}{17}$, and $\frac{11}{17}$. *Ans.* $1\frac{13}{17}$.
Add together $\frac{4}{11}$, $\frac{5}{11}$, $\frac{6}{11}$, $\frac{7}{11}$, $\frac{9}{11}$, and $\frac{10}{11}$. *Ans.* $3\frac{8}{11}$.
Add together $\frac{3}{8}$, $\frac{5}{8}$, $\frac{1}{8}$, and $\frac{7}{8}$. *Ans.* 2.
Add together $\frac{2}{37}$, $\frac{4}{37}$, $\frac{6}{37}$, $\frac{8}{37}$, and $\frac{1}{37}$. *Ans.* $\frac{21}{37}$.

To bring fractions having different denominators to fractions having one common denominator (that is, a denominator common to all the fractions):

First, put all the denominators down in a row.

Second, cancel all the denominators that are alike, except one. That is, if there are three denominators alike, two of them would be canceled and one would be left.

For instance, if in a row of denominators there happened to be three fives, as follows, 5, 5, 5, two of them would be canceled. Thus:

$$\cancel{5},\ \cancel{5},\ 5$$

and one would be left. If there were four fives, three of them would be canceled.

Third, then cancel all the denominators that will divide another without a remainder. By that is meant, the smaller denominators that will divide the larger are canceled, the larger one which can be divided is not altered, the smaller ones being left out (canceled), because they will divide the larger.

For instance, if a row of denominators consisted of the numbers, 2, 3, 7, 5, 10, 11, the 2 and 5, which will divide the 10, would be canceled, as shown:

$$\cancel{2},\ 3,\ 7,\ \cancel{5},\ 10,\ 11$$

Having canceled all the numbers that are alike, except one, and struck off the numbers that will divide others without a remainder, the fourth thing to do is —

Take all the remaining numbers and place them in a row.

Fifth, then see if any number will divide two or more of them (not less than two); if so, divide by it and place in the quotient those numbers which cannot be divided.

For instance, if the numbers left were 12, 7, 16, 5, they would be placed in a row as follows:

12, 7, 16, 5

It is seen that the number 4 will divide two of these numbers, 12 and 16, without any remainder, so divide by it and also place in the quotient the numbers 7 and 5, which cannot be divided by 4. Thus:

$$\begin{array}{r|l} 4 & \underline{12,\ 7,\ 16,\ 5} \\ & \ \ 3,\ 7,\ \ 4,\ 5 \end{array}$$

And as no two of these quotient numbers, 3, 7, 4, 5, can be divided by any number, we divide no further.

Multiply all the numbers in the quotient together and multiply their product by the divisor.

In this case the numbers 3, 7, 4, 5 would be multiplied together, and the product 420 is multiplied by the divisor 4.

The product 1680 obtained is the common denominator. That is, 1680 is the common denominator of a number of fractions whose denominators are 12, 7, 16, 5.

It will often happen that two or more of the quotient numbers may, in turn, be divided by some number. When the case is such, proceed to divide as before.

For instance, if the remaining numbers were 12, 16, 10, 35, we would first divide the 12 and 16 by 4 and place in the quotient the numbers 10 and 35, which

could not be divided by 4 without any remainder, as follows:

$$\begin{array}{r|l} 4) & \underline{12,\ 16,\ 10,\ 35} \\ 5) & \underline{\ 3,\ \ 4,\ 10,\ 35} \\ & \ 3,\ \ 4,\ \ 2,\ \ 7 \end{array}$$

Now in the quotient 3, 4, 10, 35, there are two numbers, 10 and 35, which can be divided by 5, so we place the 5 in the divisor and proceed to divide by it, placing in the quotient the figures 3 and 4, which cannot be divided, as shown. Then, as before, multiply all the quotient figures together and multiply their product by the divisors, and the result of the multiplication is the common denominator.

In this case the numbers 3, 4, 2, 7 would be multiplied together, and the product 168 is multiplied by the divisors 5 and 4, and the result of the multiplication, 3360, is the common denominator of a number of fractions whose denominators are 12, 16, 10, 35.

Lastly, divide the common denominator by the denominator of the first fraction and multiply the quotient by its numerator, and the product obtained is the new numerator required.

Then, in short, to bring fractions having different denominators to fractions having one common denominator, place all the denominators in a row; cancel all that are alike, except one. Also cancel any that will divide into another one without remainder.

If there is any number that will divide two or more of those left, then divide by it, putting down those numbers that cannot be divided. Repeat this till all the numbers are prime numbers.

A prime number is a number which cannot be divided without a remainder by any number except itself and unity.

Then multiply all the prime numbers together and their product by the divisor; the result will be the common denominator for all the fractions. Then divide the common denominator by the denominator of the first fraction and multiply the quotient by its numerator; its product is the new numerator required. Repeat this for each fraction.

Example. $\frac{1}{2}$, $\frac{5}{6}$, $\frac{2}{3}$, $\frac{3}{8}$, $\frac{1}{3}$, $\frac{5}{8}$, $\frac{7}{12}$, $\frac{5}{16}$, $\frac{1}{8}$, and $\frac{3}{4}$. Bring these fractions to other fractions having a common denominator.

All the denominators placed in a row:

$$2, 6, 3, 8, 3, 8, 12, 16, 8, 4$$

There are two figures 3, cancel one of them. Next the 2 and the 8 (two of them) and the 4 will go into the 16, therefore they must be canceled; the 6 and 3 also, because they will divide the 12. Then there only remain two, 12 and 16; place them as below and divide them by 4, because 4 will divide them both without a remainder.

$$\cancel{2}, \cancel{6}, \cancel{3}, \cancel{8}, \cancel{3}, \cancel{8}, 12, 16, \cancel{8}, \cancel{4}$$

$$\begin{array}{r|l} 4 & 12,\ 16 \\ \hline & 3,\ \ 4 \end{array}$$

Then multiply the 3 by the 4 equals 12 and multiply the 12 by the divisor 4 equals 48, and the 48 thus obtained is the common denominator. Lastly, bring each fraction to one having the denominator 48.

$$\frac{1}{2}, \frac{5}{6}, \frac{2}{3}, \frac{3}{8}, \frac{1}{3}, \frac{5}{8}, \frac{7}{12}, \frac{5}{16}, \frac{1}{8}, \frac{3}{4}$$

Answer:

$$\frac{24}{48}, \frac{40}{48}, \frac{32}{48}, \frac{18}{48}, \frac{16}{48}, \frac{30}{48}, \frac{28}{48}, \frac{15}{48}, \frac{6}{48}, \frac{36}{48}$$

This is done, as before explained, by dividing the common denominator by the denominators of each of the fractions, and multiplying the quotient by the numerator.

The denominator 2 of the first fraction $\frac{1}{2}$ goes into the common denominator, 48, 24 times. Multiply the numerator 1 by the quotient 24, and the product 24 is the new numerator. Do likewise with the remaining fractions, dividing the denominator of each fraction into the common denominator and multiply the quotient by its numerator, the product being the new numerator. The denominators of the several fractions which are brought to other fractions having a common denomitor must divide the "common denominator" an even number of times.

To add together fractions having different denominators:

First bring them to fractions having one common denominator, then add together all the numerators found by dividing the several denominators with the common denominator and multiplying the quotient by the numerator, the number obtained by the addition being the new numerator, which place on the right of the several fractions and underneath it place the common denominator.

EXAMPLE. Add together, $\frac{4}{5}$, $\frac{2}{3}$, $\frac{3}{4}$, $\frac{7}{10}$, and $\frac{1}{2}$.

$$2\underline{)\cancel{5},\ 3,\ 4,\ 10,\ \cancel{2}}$$

$$\begin{array}{r} 3,\ 2,\ \ 5 \\ \underline{2} \\ 10 \\ \underline{3} \\ 30 \\ \underline{2} \\ 60 \end{array} \text{ common denominator.}$$

$$\frac{48 + 40 + 45 + 42 + 30}{60} = \frac{205}{60} = 3\tfrac{25}{60} = 3\tfrac{5}{12}\,Ans.$$

Add together $\frac{2}{3}$, $\frac{3}{4}$, $\frac{5}{6}$, and $\frac{7}{8}$.

$$
\begin{array}{r}
2\underline{)\cancel{2},\ \cancel{4},\ \cancel{6},\ \cancel{8}} \\
\cancel{2},\ \cancel{4},\ 6,\ 8 \\
2\underline{)6,\ 8} \\
3,\ 4 \\
\underline{3} \\
12 \\
\underline{2} \\
24
\end{array}
\quad \text{common denominator}
$$

$$\frac{16 + 18 + 20 + 21}{24} = \frac{75}{24} = 3\tfrac{3}{24} = 3\tfrac{1}{8}$$

As stated before, compound fractions must be reduced to single ones, whole numbers and mixed numbers to improper fractions, and then all are reduced to their lowest terms before finding the common denominator.

Example. Add together $4\frac{3}{4}$, $5\frac{6}{7}$, and 7.

Showing the mixed and whole numbers, $\frac{19}{4}$, $\frac{41}{7}$, $\frac{7}{1}$, reduced to improper fractions,

$$
\begin{array}{r}
4\ 7\ 1 \\
\underline{7} \\
7 \\
\underline{4} \\
28
\end{array}
\quad \text{common denominator}
$$

$$\frac{133 + 164 + 196}{28} = \frac{493}{28} = 17\tfrac{17}{28}$$

As shown, the mixed numbers $4\frac{3}{4}$ and $5\frac{6}{7}$, and the whole number 7, are reduced first to the improper fractions, $\frac{19}{4}$, $\frac{41}{7}$, $\frac{7}{1}$.

The common denominator, 28, is then found, and the different denominators are divided into it and the quotients obtained are multiplied by the different numerators. By dividing the common denominator by the first denominator, 4, and multiplying the quotient 7 by the numerator 19, we get the product 133. By dividing the

common denominator, 28, by the next denominator, 7, and multiplying the quotient 4 obtained by the numerator 41, we get the product 164. Then divide the common denominator by the last denominator, 1, and as 1 goes into 28 just 28 times, the quotient 28 is multiplied by the numerator 7, the product of which is 196.

As shown, the three products, 133, 164, and 196, are added together and their sum, which equals 493, is the new numerator, and it is placed on the right of the several fractions, with the common denominator, 28, underneath it, thus, $\frac{493}{28}$, which fraction is then reduced to its simplest form.

EXAMPLE. Add $\frac{1}{2}$ of $\frac{3}{8}$ to $6\frac{3}{8}$.

$$\frac{1}{2} \text{ of } \frac{3}{8} \text{ to } 6\tfrac{3}{8}$$

When reduced to single fraction $\quad \dfrac{3}{16} \text{ to } \dfrac{51}{8} \quad$ When reduced to improper fraction

Common denominator, 16 $\quad \cancel{8}$.

$$\frac{3+102}{16} = \frac{105}{16} = 6\tfrac{9}{16}$$

As shown, the compound fraction $\frac{1}{2}$ of $\frac{3}{8}$ is reduced to the single fraction $\frac{3}{16}$, and the mixed number $6\frac{3}{8}$ to an improper fraction $\frac{51}{8}$.

As shown, we then have $\frac{3}{16}$ and $\frac{51}{8}$ to add together.

EXAMPLES FOR EXERCISE

Add together $\frac{1}{2}$, $\frac{3}{4}$, $\frac{1}{4}$, and $\frac{5}{8}$. *Ans.* $2\frac{1}{8}$.

Add together $\frac{3}{4}$, $\frac{5}{6}$, $\frac{3}{8}$, and $\frac{2}{3}$. *Ans.* $2\frac{5}{8}$.

Add together $\frac{4}{5}$, $\frac{7}{10}$, $\frac{5}{12}$, and $\frac{5}{6}$. *Ans.* $3\frac{13}{60}$.

Add together $\frac{1}{4} + \frac{1}{2} + \frac{3}{4} + \frac{5}{8} + \frac{7}{8} + \frac{13}{16} + \frac{7}{16}$. *Ans.* $4\frac{1}{4}$.

Add together $\frac{3}{7} + \frac{5}{2} + \frac{1}{2} + \frac{3}{4} + \frac{3}{10} + \frac{5}{8}$. *Ans.* $5\frac{29}{280}$.

Add together $\dfrac{\frac{1}{2}}{\frac{3}{4}} + \dfrac{4\frac{3}{8}}{12\frac{1}{4}}$ *Ans.* $1\frac{7}{294}$.

Add $\frac{2}{3}$ of $\frac{3}{4}$ to $\frac{5}{6}$ of $\frac{7}{8}$. *Ans.* $3\frac{1}{8}$.

Add $18\frac{3}{4}$ to $17\frac{5}{12}$. *Ans.* $36\frac{1}{6}$.

Add together, $4\frac{3}{4}$, $5\frac{6}{7}$, and 7. *Ans.* $17\frac{17}{28}$.

Subtraction of Vulgar Fractions

Subtraction of vulgar fractions is the process of finding the difference between fractions of different values.

Process. Reduce all compound fractions to single fractions, and reduce all whole numbers and mixed numbers to improper fractions, and when the denominators of the fractions to be subtracted one from the other are different, bring the fractions to others having a common denominator, as in addition, and subtract the smaller from the larger numerator. Bear in mind that the sign $-$ reads minus, and means that the number after it is to be subtracted from the number before it.

Example. From $\frac{7}{15}$ take $\frac{5}{21}$.

First, find the common denominator as in addition. Thus:

$$\begin{array}{r} 3\underline{)15,\ 21} \\ 5,\ \ 7 \\ \underline{5} \\ 35 \\ \underline{3} \\ 105 \end{array} = \text{common denominator.}$$

$$\frac{49-25}{105}=\frac{24}{105} \quad \text{Answer.}$$

Example. From $\frac{11}{18}$ take $\frac{3}{21}$. Thus:

$$\begin{array}{r} 3\underline{)18,\ 21} \\ 6,\ \ 7 \\ \underline{6} \\ 42 \\ \underline{3} \\ 126 \end{array} = \text{common denominator.}$$

Divide now, new common denominator, 126, by the denominator 18 of the first fraction, and multiplying the quotient 7, obtained by the divisor, by its numerator 11, you get a product of 77, which is the new numerator for that fraction, and by dividing the common denominator, 126, by the denominator 21 of the next fraction, and multiplying the quotient by its numerator 3, you get the product 18, which is the new numerator for that fraction. You then have the numerators 77 and 18; the smaller being subtracted from the larger leaves 59, which is the new numerator, as shown.

$$\frac{77-18}{126}=\frac{59}{126}$$

Then the difference between $\frac{11}{18}$ and $\frac{3}{21}$ equals $\frac{59}{126}$.

Example. From $\frac{2}{5}$ of $\frac{9}{11}$ take $\frac{1}{16}$ of $\frac{2}{7}$.

Reduce the compound fractions to single fractions.

Proceed then, as before, by bringing the fractions thus found to others having a common denominator, as follows:

From $\frac{2}{5}$ of $\frac{9}{11}$ take $\frac{1}{16}$ of $\frac{2}{7}$.

Reduce above to single fractions. From $\frac{18}{55}$ take $\frac{2}{112}$.

$$\begin{array}{rr} 55 & 112 \\ & 55 \\ \hline & 560 \\ & 560 \\ \hline & 6160 \end{array}$$

6160, common denominator.

New numerators of the above fractions, found by dividing the common denominator by the numerators and multiplying the quotient by the numerators:

$$\frac{2016-110}{6160}=\frac{\cancel{1906}}{\cancel{6160}}=\frac{953}{3080}\ \textit{Ans.}$$

EXAMPLE. From $6\frac{3}{4}$ take $\frac{3}{4}$ of $\frac{9}{12}$.

Above reduced to its simplest terms:

$$\frac{27}{4} \text{ take } \frac{\cancel{3}}{4} \text{ of } \frac{9}{\underset{4}{\cancel{12}}} = \frac{9}{16}$$

$$\frac{27}{4} \text{ take } \frac{9}{16}$$

$\cancel{4}$ 16, common denominator.

New denominators.

$$\frac{108 - 9}{16} = \frac{99}{16} = 6\tfrac{3}{16}. \textit{ Ans.}$$

EXAMPLE. From 12 take $6\frac{3}{4}$.

The above reduced to improper fractions:

$$\tfrac{12}{1} \text{ take } \tfrac{27}{4}.$$

$$\frac{48 - 27}{4} = \frac{21}{4} = 5\tfrac{1}{4}$$

As shown, the whole number 12, and the mixed number, $6\frac{3}{4}$, are reduced to improper fractions. The resulting fractions are then brought to others having a common denominator, and the smaller numerator of the fractions thus obtained is subtracted from the larger, and the difference, 21, is the new numerator, as shown.

EXAMPLE. Which is the greater, $\frac{1}{3}$ of $\frac{9}{10}$, or $\frac{5}{6}$ of $\frac{8}{15}$?

$$\frac{1}{\cancel{3}} \text{ of } \frac{\overset{3}{\cancel{9}}}{10} = \frac{3}{10} \text{ and } \frac{\cancel{5}}{\underset{3}{\cancel{6}}} \text{ of } \frac{\overset{4}{\cancel{8}}}{\underset{3}{\cancel{15}}} = \frac{4}{9}$$

Compound fractions reduced to simplest forms:

$$\tfrac{3}{10} \text{ and } \tfrac{4}{9}.$$

$$\frac{27 - 40}{90} = \frac{13}{90}$$

Then, $\frac{5}{6}$ of $\frac{8}{15}$ is the greater by $\frac{13}{90}$.

Examples for Exercise

From $\frac{1}{2}$ take $\frac{1}{4} = \frac{1}{4}$. *Ans.*
From $\frac{7}{16}$ take $\frac{1}{7} = \frac{33}{112}$. *Ans.*
From $\frac{6}{15}$ take $\frac{2}{17} = \frac{72}{255}$. *Ans.*

What is the difference between $\frac{3}{7}$ of $\frac{5}{9}$ and $1\frac{1}{2}$ of $\frac{4}{9}$? *Ans.* $\frac{3}{7}$.

Which is the greater, $3\frac{3}{8}$ of $2\frac{2}{9}$ or $8\frac{1}{3}$ of $1\frac{4}{5}$? *Ans.* The second is twice as great as the first quantity.

What is the difference between $\frac{3}{5}$ of $\frac{6}{13}$, and $\frac{1}{2}$ of $\frac{3}{11}$? *Ans.* $\frac{201}{1430}$.

From 13 take $5\frac{3}{4}$. *Ans.* $7\frac{1}{4}$.

What is the difference between $\frac{3}{8}$ of $14\frac{3}{4}$, and $\frac{3}{5}$ of $9\frac{7}{8}$? *Ans.* $\frac{63}{160}$.

From $\frac{7}{8}$ of $14\frac{3}{4}$ take $\frac{3}{5}$ of $9\frac{7}{8}$. *Ans.* $6\frac{157}{160}$

Multiplication of Vulgar Fractions

Multiplication of fractions is the process of multiplying fractions together.

Process. First bring all compound fractions to single fractions and reduce all mixed numbers and whole numbers to improper fractions. In other words, bring each fraction to its simplest form. Then multiply the numerators together for the new numerator, and the denominators together for the new denominator, and reduce the resulting fraction to its simplest form.

As before stated, the sign $\times$ reads "multiply," and means that the number before it is to be multiplied by the number after it.

Example. Multiply $\frac{4}{7}$ by $1\frac{5}{16}$. That is:

$$\frac{4}{7} \times \frac{21}{16} = \frac{84}{112} = \frac{21}{28} = \frac{3}{4}$$

As shown, the mixed number $1\frac{5}{16}$ was brought to the improper fraction $\frac{21}{16}$. The numerators 4 and 21 are then multiplied together for the new numerator, 84, and

the denominators are multiplied together for the new denominator, and the resulting fraction, $\frac{84}{112}$, is reduced to its simplest terms, $\frac{3}{4}$, which is the answer.

This same example can be worked out by canceling as follows:

Multiply $\frac{4}{7}$ by $1\frac{5}{16}$.

$$\frac{\overset{1}{\cancel{4}}}{\cancel{7}} \times \frac{\overset{3}{\cancel{21}}}{\underset{4}{\cancel{16}}} = \frac{3}{4}$$

The 4 cancels into the 16 four times, and the 7 into the 21 three times Then, $1 \times 3 = 3$, and $1 \times 4 = 4$. *Ans.* $\frac{3}{4}$.

Example. Multiply $\frac{5}{9}$ by $\frac{3}{10}$, as follows:

$$\frac{5}{9} \times \frac{3}{10} = \frac{15}{90} = \frac{1}{6} \text{ \textit{Ans.}}$$

or by canceling:

$$\frac{\overset{1}{\cancel{5}}}{\underset{3}{\cancel{9}}} \times \frac{\overset{1}{\cancel{3}}}{\underset{2}{\cancel{10}}} = \frac{1}{6} \text{ \textit{Ans.}}$$

It is seen by referring to the above example that multiplying one fraction by another is the same thing as reducing compound fractions to simple ones.

Example. Multiply, $2\frac{1}{10}$ of $3\frac{4}{7}$ by $6\frac{1}{8}$ of $\frac{8}{21}$.

The above mixed numbers, when reduced to improper fractions:

$$\frac{21}{10} \text{ of } \frac{25}{7} \times \frac{49}{8} \text{ of } \frac{8}{21}.$$

$$\frac{\overset{3}{\cancel{21}}}{\underset{2}{\cancel{10}}} \text{ of } \frac{\overset{5}{\cancel{25}}}{\underset{1}{\cancel{7}}} \times \frac{\overset{7}{\cancel{49}}}{\cancel{8}} \text{ of } \frac{\cancel{8}}{\underset{3}{\cancel{21}}}$$

The above compound fractions, after canceling and being reduced to simple fractions:

$$\tfrac{15}{2} \times \tfrac{7}{3} = \tfrac{105}{6} = 17\tfrac{1}{2}. \quad \textit{Ans.}$$

$$\text{or } \frac{\overset{5}{\cancel{15}}}{2} \times \frac{7}{\cancel{3}} = \frac{35}{2} = 17\tfrac{1}{2}. \quad \textit{Ans.}$$

Then:

$$2\tfrac{1}{10} \text{ of } 3\tfrac{4}{7} \times 6\tfrac{1}{8} \text{ of } \tfrac{8}{21} = 17\tfrac{1}{2}$$

EXAMPLES. Multiply $8\frac{3}{8}$ by 4.

$$\frac{67}{\cancel{8}} \times \frac{\cancel{4}}{1} = \frac{268}{8} = 33\tfrac{1}{2}. \quad \textit{Ans.}$$

EXAMPLE. Multiply 82 by $\frac{9}{11}$.

$$\tfrac{82}{1} \times \tfrac{9}{11} = \tfrac{738}{11} = 67\tfrac{1}{11}. \quad \textit{Ans.}$$

EXAMPLES FOR EXERCISE

Multiply $5\frac{3}{4}$ by $2\frac{5}{8}$. *Ans.* $15\frac{3}{32}$.

$$\frac{1}{2} \text{ of } \frac{2}{3} \text{ of } \frac{3}{4} \times \frac{3}{5} \text{ of } \frac{5}{6} \text{ of } \frac{2}{7}. \quad \textit{Ans. } \tfrac{1}{28}.$$

$$\tfrac{87}{96} \times 48. \quad \textit{Ans. } 43\tfrac{1}{2}.$$

$$\tfrac{1}{2} \text{ of } 2\tfrac{1}{4} \times \tfrac{2}{3} \text{ of } 3\tfrac{1}{2}. \quad \textit{Ans. } 2\tfrac{15}{24}.$$

$$\tfrac{3}{4} \text{ of } \tfrac{4}{6} \text{ of } \tfrac{12}{15} \times \tfrac{5}{6} \text{ of } 4\tfrac{1}{2}. \quad \textit{Ans. } 1\tfrac{1}{2}.$$

$$4\tfrac{2}{7} \times 1\tfrac{1}{10}. \quad \textit{Ans. } 2\tfrac{18}{35}.$$

$$\frac{\frac{3}{7}}{12} \times \frac{\frac{8}{1}}{5}. \quad \textit{Ans. } \tfrac{2}{35}.$$

DIVISION OF VULGAR FRACTIONS

Division of fractions is the process of obtaining the number of times one fraction is contained in another.

A fraction may be divided by either dividing its numerator or by multiplying its denominator.

EXAMPLE. Divide $\frac{4}{11}$ by 2.

Here we have $\frac{4}{11}$ of a whole thing which is composed

of 11 equal parts, and those four one-elevenths ($\frac{4}{11}$) are to be divided by 2. It is here evident that by dividing the numerator 4 of the fraction $\frac{4}{11}$ by 2, and placing the quotient over the denominator, the resulting fraction will be the required answer. Thus: $\frac{4}{11}$ divided by 2 = $\frac{2}{11}$. *Ans.*

Instead, now, of dividing the numerator 4 of the fraction $\frac{4}{11}$, by 2, multiply the denominator 11 by 2 and place the product underneath the numerator and reduce the resulting fraction to its lowest terms. The same result will be obtained as was obtained by dividing the numerator 4 by 2. Thus:

$$\frac{4}{11} \times 2 = \frac{\cancel{4}}{\cancel{22}} = \frac{2}{11}. \quad \textit{Ans.}$$

It is here fully demonstrated that either dividing the numerator or multiplying the denominator divides a fraction; however, for convenience, operations in division are performed by inverting the terms of the division, that is, by placing the denominator above the horizontal line and the numerator below it, as shown in following examples.

It will be remembered that the sign ÷ reads "divide by," and means that the number before it is to be divided by the number after it. Thus:

$$\tfrac{4}{11} \div 2 = \tfrac{4}{11} \times 2 = \tfrac{4}{22} = \tfrac{2}{11}. \quad \textit{Ans.}$$

Example. Divide $\frac{8}{17}$ by 5. Thus:

$$\tfrac{8}{17} \div 5 = \tfrac{8}{17} \times 5 = \tfrac{8}{85}. \quad \textit{Ans.}$$

Example. Divide $\frac{2}{7}$ by 6. Thus:

$$\tfrac{2}{7} \div 6 = \tfrac{2}{7} \times 6 = \tfrac{2}{42} = \tfrac{1}{21}. \quad \textit{Ans.}$$

Example. Divide 14 by $\frac{3}{7}$. Thus:

$$14 \div \tfrac{3}{7} = 14 \times \tfrac{7}{3} = \underline{98}$$

$$\begin{array}{r} 3)98(32\tfrac{2}{3}. \quad \textit{Ans.} \\ \underline{9} \\ 8 \\ \underline{6} \\ \underline{2} \\ 3 \end{array}$$

EXAMPLE. Divide 32 by $\frac{9}{11}$. Thus:

$$32 \div \tfrac{9}{11} = 32 \times \tfrac{11}{9} = \underline{352}$$

$$\begin{array}{r} 9)352(39\tfrac{1}{9}. \quad \textit{Ans.} \\ \underline{27} \\ 82 \\ \underline{81} \\ \underline{1} \\ 9 \end{array}$$

All mixed numbers and whole numbers must be reduced to improper fractions, and all compound fractions reduced to single fractions, before dividing.

EXAMPLE. Divide $1\frac{3}{4}$ by $1\frac{1}{8}$.

Reduce first the mixed numbers to improper fractions, then proceed to divide. Thus:

$$1\tfrac{3}{4} \div 1\tfrac{1}{8}$$

Above reduced to improper fractions.

$$\tfrac{7}{4} \div \tfrac{9}{8}$$

Then

$$\frac{7}{4} \div \frac{9}{8} = \frac{7}{4} \times \frac{8}{9} = \frac{56}{36} = 1\tfrac{5}{9}$$

EXAMPLE. Divide $\frac{3}{4}$ by $1\frac{1}{8}$, that is:

$$\tfrac{3}{4} \div \tfrac{9}{8} = \tfrac{3}{4} \times \tfrac{8}{9} = \tfrac{24}{36} = \tfrac{2}{3}. \quad \textit{Ans.}$$

EXAMPLE. Divide $\frac{3}{4}$ of 2 by $\frac{3}{4}$ of 7.

Reduce first all whole numbers to improper fractions.

Thus:

$$\tfrac{3}{4} \text{ of } \tfrac{2}{1} \div \tfrac{3}{4} \text{ of } \tfrac{7}{1}$$

Reduce, then, above compound fractions to single fractions. Thus:

$$\tfrac{3}{4} \text{ of } \tfrac{2}{1} \div \tfrac{3}{4} \text{ of } \tfrac{7}{1}$$

Above reduced to single fractions:

$$\tfrac{6}{4} \div \tfrac{21}{4}$$

Then

$$\tfrac{6}{4} \div \tfrac{21}{4} = \tfrac{6}{4} \times \tfrac{4}{21} = \tfrac{24}{84} = \tfrac{2}{7}. \quad \textit{Ans.}$$

EXAMPLE. Divide $4\frac{2}{7}$ of $\frac{14}{15}$ by $3\frac{3}{4}$ of $3\frac{1}{5}$. That is:

$$\tfrac{30}{7} \text{ of } \tfrac{14}{15} \div \tfrac{15}{4} \text{ of } \tfrac{16}{5}$$

That is:

$$\frac{\overset{2}{\cancel{30}}}{\underset{1}{\cancel{7}}} \text{ of } \frac{\overset{2}{\cancel{14}}}{\cancel{15}} \div \frac{\overset{3}{\cancel{15}}}{\cancel{4}} \text{ of } \frac{\overset{4}{\cancel{16}}}{\cancel{5}} = \frac{4}{1} \times \frac{1}{12} = \frac{4}{12} = \frac{1}{3}. \quad \textit{Ans.}$$

Canceling, as shown above, reduces the dividend to $\frac{4}{1}$ and the divisor to $\frac{12}{1}$.

EXAMPLES FOR EXERCISE

$\frac{1}{2} \div \frac{2}{3}$ *Ans.* $\frac{3}{4}$.

$\frac{1}{2} \div \frac{1}{4}$ *Ans.* 2.

$\frac{3}{4} \div \frac{1}{2}$ *Ans.* $1\frac{1}{2}$.

$3\frac{1}{2} \div \frac{4}{7}$ *Ans.* $6\frac{1}{8}$.

$\dfrac{\frac{7}{8}}{\frac{3}{11}}$ of $12\frac{1}{2} \div \dfrac{\frac{1}{3}}{7\frac{1}{2}}$ of $8\frac{3}{4}$. *Ans.* $103\frac{1}{8}$.

$5\frac{5}{6} \div 2\frac{1}{5}$. *Ans.* $2\frac{43}{66}$.

$4\frac{3}{7}$ of $\frac{14}{15} \div 3\frac{3}{4}$ of $3\frac{1}{5}$. *Ans.* $\frac{31}{90}$.

$\frac{2}{3}$ of $\frac{7}{8} \div \frac{1}{7}$ of $\frac{2}{9}$. *Ans.* $18\frac{3}{8}$.

$\frac{3}{4}$ of $\frac{5}{7}$ of $\frac{4}{9} \div \frac{2}{3}$ of $\frac{6}{7}$ of $\frac{2}{18}$. *Ans.* $3\frac{63}{84}$.

DECIMAL FRACTIONS

The term "decimal" is derived from the Latin word deci, or decimus, which means ten or tenth.

The decimal system of figures is very old and in all probability originated from the use of the ten fingers as helps to count.

It is supposed that in India there was in use, as early as A.D. 525, an imperfect form of our present decimal system. The system was not used in Europe till about 1200, when it was introduced through the Arabians. According to the decimal system, ten or some multiple of ten units of a lower denomination make one unit of the next higher denomination.

Our present money system, for instance, is a decimal system, because:

10 mills make one cent.
10 cents make one dime.
10 dimes make one dollar.
10 dollars make one eagle.

According to the decimal system, a dot, thus (.), called the decimal point, separates the unit from the fractional parts of an expression. Thus, in the following decimal expression:

$$354.5$$

the 354 represents units and the .5 represents the fractional parts of a unit. A decimal fraction is one whose denominator is always 10 or 100 or 1000, or some other power (as it is called) of 10, but its numerator may be any number.

For example, $\frac{1}{10}$, $\frac{1}{100}$, $\frac{1}{1000}$, $\frac{3}{10}$, $\frac{6}{100}$, are all decimal fractions.

Strictly speaking, there should be as many figures in

the numerator as there are cyphers in the denominator; and if there are not as many, they may be made so by attaching cyphers to the left of the given numerator.

For example, the five fractions above would be:

$$\frac{1}{10}, \frac{01}{100}, \frac{001}{1000}, \frac{3}{10}, \frac{06}{100}.$$

This being the case, the denominator can be done away with, a dot, thus (.), being placed before the numerator.

A decimal fraction, then, is always represented by one number having a dot before it; that is:

$\frac{1}{10}$ is written .1 and is in value equal to one tenth of a whole number.

$\frac{7}{10}$ is written .7, and is in value equal to seven tenths of a whole number.

$\frac{01}{100}$ is written .01, and is in value equal to one hundredth of a whole number.

$\frac{001}{1000}$ is written .001, and is in value equal to one thousandth of a whole number.

So it will be seen that, in decimals, by placing a figure one place to the right makes it a tenth of what it was before, just as in whole numbers. Thus:

1. is one whole thing.
.1 is one tenth whole thing.
.01 is one hundredth whole thing.
.001 is one thousandth whole thing, etc.

If the fractions have a numerator other than 1, thus: $\frac{5}{10}$ is written .5, $\frac{27}{100}$ is written .27, and $\frac{372}{1000}$ is written .372.

The first place on the right of the decimal point is always tenths, the second place on the right of the decimal point is always hundredths, and the third place on the right of the decimal point is always thousandths.

Knowing, then, that a decimal fraction is expressed without its denominator, by means of the decimal point,

and that it may be expressed in this way because the denominator of a decimal fraction is always 1, with as many places annexed as there are places in the decimal, proceed to express the following in decimal form:

(1) $\frac{85}{100}$ *Ans.* .85; (2) $\frac{6}{100}$ *Ans.* .06; (3) $\frac{9}{1000}$ *Ans.* .009; (4) $\frac{75}{100}$ *Ans.* .75; (5) $\frac{201}{1000}$ *Ans.* .201; (6) 349 $\frac{19}{1000000}$ *Ans.* 349.000019; (7) 12 $\frac{342}{1000}$ *Ans.* 12.342; (8) $\frac{12}{1000000}$ *Ans.*.000012.

To Bring a Decimal Fraction to a Vulgar Fraction

Process. Put down the given decimal as a numerator, leave out the decimal point, then place underneath it a denominator 1 with as many cyphers after it as there are places in the given decimal.

For instance, .25 to a vulgar fraction. Thus:

$$\frac{25}{100} = \frac{1}{4}. \ \textit{Ans.}$$

The operation was performed by omitting the decimal point and placing the denominator underneath the given numerator, then changing the fraction to its lowest terms.

Example. Bring .875 to a vulgar fraction. Thus: $\frac{875}{1000} = \frac{175}{200} = \frac{35}{40} = \frac{7}{8}$ *Ans.*

Example. Bring .87500 to a vulgar fraction. Thus: $.87500 = \frac{87500}{100000} = \frac{17500}{20000} = \frac{3000}{4000} = \frac{70}{80} = \frac{7}{8}$ *Ans.*

Which is the same as the preceding example and demonstrates that cyphers on the right of a decimal have no value. You may add as many cyphers to the right as you please, or if any are given (note the fact) you may leave them off without affecting the value of the decimal. Thus:

$$.120 = .1200 \text{ and } .12 = .120 \text{ or } .1200$$

Examples for Exercise

Bring the following decimal fractions to vulgar fractions.

1.	.025.	*Ans.* $\frac{1}{40}$.	5.	120.6.	*Ans.* $120\frac{3}{5}$.
2.	.476.	*Ans.* $\frac{119}{250}$.	6.	.581.	*Ans.* $\frac{581}{1000}$.
3.	.50.	*Ans.* $\frac{1}{2}$.	7.	.01395.	*Ans.* $\frac{279}{20000}$.
4.	.050.	*Ans.* $\frac{1}{20}$.	8.	300.98.	*Ans.* $300\frac{49}{50}$.

To Bring a Vulgar Fraction to a Decimal Fraction

Annex any number of decimal cyphers to the numerator and divide by the denominator, and point off as many decimal figures in the quotient as there are cyphers annexed to the numerator.

Example. Bring $\frac{1}{4}$ to a decimal fraction.

Proceed by placing a cypher on the right of the numerator 1, then divide this by the denominator 4, as follows, saying 4 into 10 goes 2 and 2 over. Annex then another cypher and divide by 4, again saying, 4 into 20 goes 5 times. Then mark off as many decimal figures in the quotient as there were cyphers annexed to the numerator. Thus:

```
4)1.00
   .25   Ans.
```

Example. Bring $\frac{15}{16}$ to a decimal fraction. Thus:

```
16)15.00(.9375   Ans.
   144
     60
     48
     120
     112
       80
       80
```

Sometimes, in reducing a vulgar fraction to a decimal fraction, the quotient never comes to an end, but the same figure keeps repeating itself, as $\frac{1}{6} = .16666$, etc., without end. This is called a repeating decimal and is written $.1\dot{6}$. The dot over the 6 represents that the 6 is a repeater.

Sometimes, instead of one figure repeating itself, as above, you will find two or more doing so, as $\frac{1}{7} =$ .142857142857142857, etc. Thus:

```
1/7)1.000000000000(.142857142857
      7
      ---
      30
      28
      ---
       20
       14
       ---
        60
        56
        ---
         40
         35
         ---
          50
          49
          ---
           10
            7
           ---
           30
           28
           ---
            20
            14
            ---
             60
             56
             ---
              40
              35
              ---
               50
               49
               ---
                10
```

Here it will be seen that the figures 142857 keep coming over and over, and this would continue without end. This is called a circulating decimal and is written thus, $.\dot{1}4285\dot{7}$, having a dot placed over the first and last figure of the set of figures which keep repeating.

Then, $\frac{1}{7} = .142857142857142857$ etc., and is expressed, $.\dot{1}4285\dot{7}$.

It is not often necessary to carry decimals more than six places, thus, .534678.

Reduce to decimal fractions the following: (1) $\frac{3}{4}$ *Ans.* .75; (2) $\frac{1}{2}$ *Ans.* .5; (3) $\frac{3}{8}$ *Ans.* .375; (4) $\frac{7}{8}$ *Ans.* .875; (5) $\frac{3}{16}$ *Ans.* .125; (6) $\frac{11}{16}$ *Ans.* .6875; (7) $\frac{14}{20}$ *Ans.* .7; (8) $\frac{8}{25}$ *Ans.* .32; (9) $\frac{5}{6}$ *Ans.* $.8\dot{3}$; (10) $\frac{11}{12}$ *Ans.* $.91\dot{6}$.

To Reduce a Mixed Number to a Decimal Fraction

First, reduce the mixed number to an improper fraction, then reduce the improper fraction to a decimal fraction.

EXAMPLE. Reduce $4\frac{1}{64}$ to a decimal.

$$
\begin{array}{l}
64)257.000000(4.015625 \quad \textit{Ans.} \\
\quad\ \ \underline{256} \\
\qquad\ \ 100 \\
\qquad\ \ \ \underline{64} \\
\qquad\ \ \ 360 \\
\qquad\ \ \ \underline{320} \\
\qquad\quad 400 \\
\qquad\quad \underline{384} \\
\qquad\qquad 160 \\
\qquad\qquad \underline{128} \\
\qquad\qquad\ \ 320 \\
\qquad\qquad\ \ 320
\end{array}
$$

Then, $4\frac{1}{64} = \frac{257}{64} = 4.015625$.

EXAMPLE. Reduce $11\frac{1}{2}$ to a decimal.

$$11\tfrac{1}{2} = \frac{23}{2}$$

$$\begin{array}{r} 2)23.0(11.5 \\ \underline{22} \\ 10 \\ \underline{10} \end{array}$$

Then $11\frac{1}{2} = \frac{23}{2} = 11.5$ *Ans.*

To reduce a decimal fraction to any particular vulgar fraction, multiply the given decimal by the denominator you wish to bring it to, then mark off as many decimals, from right to left, as there are places in the given decimal, and whatever number is to the left of the decimal point is the required numerator.

EXAMPLE. How many sixteenths are there in .198?

$$\begin{array}{r} .198 \\ \underline{16} \\ 1188 \\ \underline{198} \\ 3.168 \end{array}$$ *Ans.* (a little over $\frac{3}{16}$)

EXAMPLE. How many halves in .5?

$$\begin{array}{r} .5 \\ \underline{2} \\ 1.0 \end{array}$$ *Ans.* 1

EXAMPLE. How many fourths in .75?

$$\begin{array}{r} .75 \\ \underline{4} \\ 3.00 \end{array}$$ *Ans.* 3 (three fourths).

ADDITION OF DECIMALS

PROCESS. Place the quantities in such manner that the decimal point of one line shall be directly under that

of every other line, and arrange units under units, tenths under tenths, hundredths under hundredths. Then add as in whole numbers, placing the decimal point in the sum directly underneath those above.

EXAMPLE. Add together, 18; 74; 3.98046; 273.4; 15.0071; .04527. Thus:

$$\begin{array}{r@{}l} 18 & \\ 74 & \\ 3 & .98046 \\ 273 & .4 \\ 15 & .0071 \\ & .04527 \\ \hline 384 & .43283 \end{array}$$

EXAMPLES FOR EXERCISE

Add together:

(1) 30.034; 2135.2; 27.03; 2.34071. *Ans.* 2194.60471.

(2) 15.17; 2.3876; 403.20104; 12.5. *Ans.* 433.25864.

(3) 246.03; 00.674; 5.012; 15.999. *Ans.* 267.715.

(4) Find the sum of 327.05 + 12.491 + 16.25 + 642.75 *Ans.* 998.541.

(5) What is the sum of 5.0327 + 491.12 + 25.16 + 75.2. *Ans.* 596.5127.

SUBTRACTION OF DECIMAL FRACTIONS

PROCESS. Place the less number under the greater, with decimal point under decimal point, as in addition. If one line has more decimal figures than the other, put noughts at the end of the one that is deficient till they are equal, then subtract, as in single subtraction, and point off as many places for decimals as there are in the number which contains the greater number of decimals.

EXAMPLE. From 232.5003 take 76.8973.

$$\begin{array}{r} 232.5003 \\ 76.8973 \\ \hline 155.6030 \end{array} \quad \textit{Ans.}$$

As shown, the less number is written under the greater, arranging units under units, tenths under tenths, hundredths under hundredths, etc. Then the less number is subtracted from the greater, as in whole numbers.

EXAMPLE. From 4.17 take 2.893652.

$$\begin{array}{r} 4.170000 \\ 2.893652 \\ \hline 1.276348 \end{array} \quad \textit{Ans.}$$

Here, as shown, one line of decimal figures is greater than the other, and at the end of the line that was deficient, noughts were placed till the number of decimal places were made equal in each line. Then we subtract as before.

EXAMPLE. From 100 take .001.

$$\begin{array}{r} 100.000 \\ .001 \\ \hline 99.999 \end{array} \quad \textit{Ans.}$$

EXAMPLES FOR EXERCISE

1. From 24.36 take 16.054267. *Ans.* 8.305733.
2. From .42052 take .1360076. *Ans.* .2845124.
3. Find the value of 467 – 43.6054 *Ans.* 423.3946.
4. Find the value of 12.036 – 5.61. *Ans.* 6.426
5. From 43.123 take 8.58195. *Ans.* 34.54105.

MULTIPLICATION OF DECIMALS

PROCESS. Multiply as in common multiplication, without taking notice of the decimal points. Add up and so get the product.

Point off as many figures for decimals in the product as there are decimals in the multiplicand and multiplier. There must be as many decimal places in the product as the sum of the decimals in the multiplicand and multiplier.

EXAMPLE. Multiply 45.32 by 6.531.

```
      45.32
      6.531
      -----
       4532
     13596
    22660
   27192
  ---------
  295.98492
```

The product first stood 29598492, but as there are altogether five decimal figures in the question (two in the multiplicand and three in the multiplier), we count five, beginning at the last figure 2, and place a decimal point before the figure that stands at the fifth place. The answer is 295.98492.

It is sometimes found that there are not as many figures in the product as there are decimal figures in the multiplicand and multiplier. In such cases, put a sufficient number of cyphers on the left of the product to make the number of decimal places equal to the sum of the decimal places in the multiplicand and multiplier.

EXAMPLE. Multiply .00052 by .0402.

```
.00052
 .0402
 -----
   104
208
-----
20904
```

Here it is seen that the product, 20904, contains five figures only, and that there are nine decimal places in the

example. We therefore place four cyphers on the left of the product, making it .000020904, which is the answer.

EXAMPLE. Multiply 4.12 by .013.

$$\begin{array}{r} 4.12 \\ \underline{.013} \\ 1236 \\ \underline{412} \\ .05356 \end{array} \quad \textit{Ans.}$$

EXAMPLES FOR EXERCISE

1. Multiply 345.2 by 32.14. *Ans.* 11094.728.
2. Multiply 42.545 by 3.42. *Ans.* 145.50390.
3. Multiply 2084 by .3055. *Ans.* 636.6620.
4. Multiply .5652 by .0025. *Ans.* .00141300.
5. Multiply .0004 by .00304. *Ans.* .000001216.
6. Multiply .0002 by .00101. *Ans.* .000000202.

DIVISION OF DECIMALS

PROCESS. When the divisor is a whole number, divide as in simple division, and when you come to the decimal point in the dividend, place a point in the quotient.

EXAMPLE. Divide 382.7838 by 2.

$$\begin{array}{r} 2)\underline{382.7838} \\ 191.3919 \end{array}$$

EXAMPLE. Divide 1537.27 by 8.

$$\begin{array}{r} 8)\underline{1537.27} \\ 192.15875 \end{array}$$

As shown, 8 into 15 goes 1 time and 7 over, then 8 into 73 goes 9 times and 1 over, then 8 into 17 goes 2 times and 1 over, 8 into 12 goes 1 time and 4 over; then after saying 8 into 47 goes 5 times and 7 over

make this 7 into 70; 8 into 70 goes 8 and 6 over; 8 into 60 goes 7 times and 4 over, 8 into 40 goes 5 times.

EXAMPLE. Divide 144.144 by 12.

$$\begin{array}{r} 12)\underline{144.144} \\ 12.012 \quad \textit{Ans.} \end{array}$$

Here we say, 12 into 144 goes 12 times, which place in the quotient. Then on the right of it, and underneath the decimal point in the dividend, place the decimal point. We then say, 12 into 1 goes no times, which place in the quotient, then 12 into 144 goes 12 times.

EXAMPLE. Divide 38.4256 by 12.

```
12)38.4256(3.20213̇
   36
    24
    24
     25
     24
      16
      12
       40
       36
        4
```

Here, after the 6, the last decimal figure in the dividend, is brought down, it goes 2 times and the remainder is 4, to this attach a cypher and let it go on again as far as it is thought necessary. Note here that the last decimal figure, 3, of the quotient, will keep repeating over and over, and, as before stated, a decimal figure that repeats is called a repeater and is expressed by placing a dot over it. Therefore, over the 3 in the quotient is placed a dot, thus, $\dot{3}$.

When the number of decimal figures in the divisor is less than the number of decimal figures in the dividend,

divide without taking notice of the decimals; then subtract the number of decimals in the divisor from the decimal figures in the dividend; the remainder will be the number of decimals to mark off in the quotient. That is, if, for instance, there was one decimal figure in the divisor and three decimal figures in the dividend, after dividing we would subtract the one decimal figure of the divisor from the three decimal figures of the dividend, and the remainder two would be the number of decimal places to mark off in the quotient.

EXAMPLE. Divide 153.4036 by .4.

$$\begin{array}{r} .4\overline{)153.4036} \\ \hline 383.509 \end{array}$$

Here there is one decimal place in the divisor and four decimal places in the dividend. So we say, 1 from 4 leaves 3, then mark off 3 decimals in the answer.

When marking off the decimal places in the quotient, mark off from right to left a sufficient number of figures so that those figures with the decimal places in the given divisor will together equal the number of decimal places in the given dividend. That is, the number of decimal places in the quotient and divisor together must be equal in number to the number of decimal places in the dividend.

EXAMPLE. Divide 182.6025 by .25.

$$\begin{array}{l} .25)182.6025(730.41 \\ \quad\;\; \underline{175} \\ \qquad\;\; 76 \\ \qquad\;\; \underline{75} \\ \qquad\;\;\; 102 \\ \qquad\;\;\; \underline{100} \\ \qquad\qquad 25 \\ \qquad\qquad \underline{25} \end{array}$$

Here we have four decimal places in the dividend and two decimal places in the divisor; therefore, we mark off in the quotient, from right to left, two decimal places. We then have in the quotient and divisor together the same number of decimal places as there are decimal places in the dividend.

EXAMPLE. Divide 136.875 by 37.5.

```
37.5)136.875(3.65
     1125
     ----
      2437
      2250
      ----
       1875
       1875
       ----
```

EXAMPLE. Divide 136.875 by 3.75.

```
3.75)136.875(36.5
     1125
     ----
      2437
      2250
      ----
       1875
       1875
       ----
```

It will sometimes happen that the number of decimals in the quotient and divisor together will not equal the number of decimals in the dividend. In such a case, prefix a sufficient number of cyphers to the figures in the quotient to supply the deficit, as shown in the following example.

Divide .525 by 7.5.

```
7.5).525(.07
     525
     ---
```

In the above example we place a cypher before the quotient figure 7, which removes it to the place of hun-

dredths and then makes the decimal places of the divisor and quotient together equal to the three decimal places of the dividend.

EXAMPLE. Divide .0123825 by .75.

```
.75).0123825(.01651
     75
     488
     450
      382
      375
       75
```

Here we divided as in whole numbers and have in the quotient four figures, 1651, to which we prefixed a cypher so that the decimal places of the quotient together with the decimal places of the divisor will equal the number of decimal places of the dividend. When there are more decimal figures in the divisor than there are in the dividend, annex as many cyphers to the decimals of the dividend as will make them equal to the number of decimals of the divisor. That is, equalize the decimals by attaching cyphers to the dividend, so that the divisor and dividend will contain the same number of decimals. Then leave out the decimal points altogether and divide as in simple division, and the quotient will be a whole number. If there is a remainder after this, attach a cypher to it and again divide; this will give the first decimal figure of the quotient; to the remainder again attach a cypher; again divide for the second decimal figure, and so on, as far as it is thought necessary.

EXAMPLE. Divide 2.2 by .550.

First equalize the decimal figures, thus, 2.200 by .550. Then leave out the decimal points, and divide thus:

```
550)2200(4   Ans.
    2200
        Ans. 4 whole numbers.
```

EXAMPLE. Divide 1562.5 by .00025.

First equalize the decimal places of the divisor and dividend by annexing cyphers to the dividend, thus, 1562.50000 by .00025; leave out the decimal points and divide as in simple division.

```
00025)156250000(6250000   Ans.
      150
      ---
        62
        50
        ---
        125
        125
        ---
```

EXAMPLE. Divide 147.24 by .84625.

Equalize 147.24000 by .84625.

```
84625)14724000(173.99, etc.
      84625
      ------
      626150
      592375
      ------
       337750
       253875
       ------
        838750
        761625
        ------
         771250
         761625
         ------
```

Referring to the above example we see that the divisor goes into the dividend once, then 7 times, and then 3 times, and as there are no more figures left to bring down, these 173 are whole numbers. To find the decimals, attach a cypher to the remainder, 83875, and it

goes 9 times. This is put in the quotient as .9 (note the decimal point); to the next remainder, 77125, attach another cypher and it goes 9 times again. Put this 9 after the former one, attach another cypher to the remainder, if thought necessary, and continue as far as you please. However, as before stated, it is not usually necessary to carry decimals more than six places.

Examples for Exercise

Divide 72.348 by 6. *Ans.* 12.058.
Divide 468.6520 by 5. *Ans.* 93.7304.
Divide 144.12 by 12. *Ans.* 12.01.
Divide 33.9316 by 16.4. *Ans.* 2.069.
Divide 176.24 by .6725. *Ans.* 262.0669.
Divide 983. by 6.6. *Ans.* $148.\dot{9}\dot{3}$.
Divide 1562.5 by .0025. *Ans.* 625000.
Divide 2944.8 by .21312. *Ans.* 13817.567, etc.
Divide 144.144 by 12.12. *Ans.* 11.8939, etc.
Divide 147.24 by .84625. *Ans.* 173.99, etc.
Divide 87916.05 by .88. *Ans.* 99904.6022, etc.
Divide 2.28125 by 62.5. *Ans.* .0365.
Divide .228125 by 62.5. *Ans.* .00365.

PROPORTION, OR THE RULE OF THREE

Proportion is the process of finding the relation of one thing to another, in respect to size, quantity, capacity, or degree. In proportion there are three quantities given, and with the three given quantities we are to find a fourth, which quantity is to bear the same relation to the third quantity as the first quantity bears to the second. Then, according to theory, proportion is the rule by which we are enabled to find the fourth proportional to three given numbers. That is, a fourth number

which will bear the same relation or ratio to the third number as the first number bears to the second.

The term "ratio" is used more or less in working out problems by the process of proportion or the rule of three, and ratio means the relation between two similar things in respect to quantity or size; that is, the relation between two like things, in respect to how many times one makes so many times the other, and is the same as quotient, which expresses how many times one quantity contains another. Then it is necessary to have two numbers to form a ratio, because ratio is the quotient arising from the division of one number by another. Thus, the ratio of 8 to 4 is 2.

Of the two numbers required to form a ratio, the first is called the antecedent and the last the consequent.

Then, in the above example, 8 is the antecedent and 4 is the consequent.

A ratio may be either direct or inverse. A direct ratio is when the antecedent is divided by the consequent, that is, when the first term is divided by the second; and an inverse ratio is when the consequent is divided by the antecedent, that is, when the second term is divided by the first. Then the direct ratio of 8 to 4 is $8 \div 4$ and the inverse ratio of 8 to 4 is $4 \div 8$.

Proportion, then, enables us to find a fourth number when there are three numbers given that will be the same ratio to the third term that the first term is to the second.

A ratio is usually expressed by two dots, thus (:), and a proportion is usually expressed by four dots, thus (::).

The sign : reads "is to."

And the sign : : reads "as."

Then when performing examples in proportion, write same thus:

$$3 : 6 :: 6 : 12$$

For instance, 3 is to 6 as 8 is to what?

Here there are three given quantities, 3, 6, and 8, and we have to find a fourth quantity that will be the same relation to 8 that 3 is to 6. The rule is to multiply the second term by the third term and divide the product by the first term, and the quotient will be the fourth term required.

EXAMPLE. 3 is to 6 as 8 is to what?

$$3:6::8:16$$

$$\begin{array}{r} 6 \\ \hline 3)\underline{48} \\ 16 \end{array}$$

16 required term which is placed above, as shown. Then 3 is to 6 as 8 is to 16.

EXAMPLE. 6 is to 3 as 16 is to what?

$$6:3::16:8$$

$$\begin{array}{r} 3 \\ \hline 6)\underline{48} \\ 8 \end{array}$$

Then 6 is to 3 as 16 is to 8.

Here, as before, multiply the second term by the third, and divide the product by the first term and the quotient is the required number.

EXAMPLE. 14: 8:: 6: what?

Thus: $14:8::6:3\frac{3}{7}$ *Ans.*

$$\begin{array}{r} 8 \\ \hline 14)48(3\frac{3}{7} \\ 42 \\ \hline 6 \\ \hline 14 \end{array} = \frac{3}{7}$$

EXAMPLE. 8: 14:: 5: what ?

Thus: 8: 14:: 5: $8\frac{3}{4}$ *Ans.*

$$\begin{array}{r} 14 \\ \hline 20 \\ 5 \\ \hline 8)\overline{70}(8\frac{3}{4} \\ 64 \\ \hline 6 \\ \hline 8 \end{array} = \frac{3}{4}$$

EXAMPLE. 10: 20:: 12: what?

Thus: 10 : 20 :: 12 : 24

$$\begin{array}{r} 20 \\ \hline 10)\overline{240} \\ \hline 24 \end{array}$$ *Ans.*

EXAMPLE. 20: 10:: 24: what?

Thus: 20: 10:: 24: 12

$$\begin{array}{r} 10 \\ \hline 20)240(12 \\ 20 \\ \hline 40 \\ 40 \\ \hline \end{array}$$ *Ans.*

It is now seen in all cases there are three quantities given, as stated before, and with the three given quantities we are to find a fourth. And we have seen that by multiplying the second term by the fourth term, and dividing the product by the first term, the quotient is the required fourth term. Now, in all cases, two of the three given terms will be of the same denominations; that is, two of the terms will always represent the same kind of a thing, and the two terms of a like denomination will always be the first and second terms of the proportion, and the other given term

will have the same denomination as the required answer, and this term will always be the third term in the proportion.

To know which is to be the first and which the second term of the proportion:

If the answer is to be greater than the third term, the greater of the like terms must be the second term of the proportion, but if the answer is to be smaller than the third term, the smaller of the like terms must be the second term of the proportion.

Example. If four men can earn $10 per week, how much will 8 men earn in the same length of time?

Here there are two terms of the same denomination, 4 men and 8 men, and one term of a different denomination, $10. The unlike denomination being the third term of the proportion, the $10 must be the third term.

To find the second term — will 8 men earn more than 4 men?

Yes. Then the 8 is the second term, consequently 4 is the first term. The proportion, therefore, is

$$4 : 8 :: 10 : \quad \textit{Ans.}$$

$$\begin{array}{r} 10 \\ \underline{8} \\ 4\overline{)80} \\ \hline 20 \end{array} \text{ dollars.} \quad \textit{Ans.}$$

If a man can earn $17 in 7 days, how many days will it take him to earn $170?

Here the 7 days will be the third term, and as the answer must be more than that, the larger number of dollars must be the second term and the smaller number of dollars the first term of the proportion.

Then, as 17 : 170 :: 7 : the answer.

17: 170::
7

17)1190(70 days
119
0

Ans. 70 days.

Example. If a man can earn \$2.50 in one day, how long will it take him to earn \$170?

Here the third term is 1 day, and as it will take him longer to earn \$170 than \$2.50 (2.50), the second term of the proportion must be \$170, and consequently the first term is \$2.50.

Then: 2.50: 170.00:: 1: the answer.
1

250)17000(68 days. *Ans.*
1500
2000
2000

Example. If a ship sails 26 knots in 4 hours, how long will it take her to sail 650, at the same rate of sailing? Here the 4 hours will be the third term, and as the answer must be more than that, the larger number of knots must be the second term and the smaller number the first term.

Then as 26: 650:: 4: the answer.
4

26)2600(100 hours. *Ans.*
26
00

or 4 days, 4 hours, of 24 hours per day.

Example. If 8 men can do a certain amount of work in 18 working days, how long should it take 12 men to do it?

It is plainly seen that it will take 12 men less time to accomplish the work than it would 8 men, therefore, the less number, 8, must be the second term. Then

$$
\begin{array}{r l}
12:8::18: & \text{the answer.} \\
8 & \\
12)\overline{144} & \\
12 & \text{days.} \quad \textit{Ans.}
\end{array}
$$

Example. If I pay $3 for twelve yards of cloth, how much will 8 yards cost?

It will manifestly take less to buy 8 yards than it takes to buy 10 yards, therefore, 8 must be the second term of the proportion. Then

$$
\begin{array}{r l}
12:8::3.00: & \text{the answer.} \\
8 & \\
12)\overline{2400} & \\
2.00 & \text{dollars.} \quad \textit{Ans.}
\end{array}
$$

Examples for Exercise

1. If 12 men earn $96 per week, what would be the wages of 3 men for the same time? *Ans.* $24.
2. If 6 paces taken by a man equals 5 yards, what is the length of a plank that is 240 paces? *Ans.* 200 yards.
3. If my expenses are $12 per week, how long will $465 last me? *Ans.* $38\frac{3}{4}$ weeks, or $271\frac{1}{4}$ days.
4. If 72 men cut 96 cords of wood per day, how many cords will 5 men cut? *Ans.* $6\frac{2}{3}$ cords.
5. If 10 men can do a certain amount of work in 50 days, how long will it take for 7 men to do the same amount of work? *Ans.* $71\frac{3}{7}$ days.
6. If 10 men engage to complete a certain amount of work in 50 days, but 3 of them are taken sick, how long will it take the rest to complete the work? *Ans.* $71\frac{1}{7}$ days.

7. If a house can be built in 14 days by a certain number of men, working 12 hours a day, how many days will it take them to build it if they work 8 hours a day? *Ans.* 21 days.

8. If a house can be built in 14 days by a certain number of men working 10 hours per day, how many days will it take them to complete it if they work 12 hours per day? *Ans.* $11\frac{2}{3}$ days.

9. If 6 men can do a certain amount of work in 14 days by working 12 hours per day, how many days will it take them to do the work if they work 8 hours per day? *Ans.* 21 days.

10. If 8 men can build a house in 90 days by working 8 hours per day, how long will it take them to build it if they work 12 hours per day? *Ans.* 60 days.

NOTE. Go over these examples thoroughly and carefully. Understand the sense of the examples and it will be a simple matter to solve them, and in order to simplify future work care must be taken that this chapter is thoroughly understood.

COMPOUND PROPORTION

To compound anything is the putting together two or more elements, and by the process of compound proportion we are enabled to perform questions by putting together two or more elements (compounding) that would require two or more operations to perform if performed by the process of simple proportion.

In compound proportion there are always two or more elements to be considered, as men, dollars, and days, for instance. We will call each denomination, for convenience, an element. In arranging numbers in the pro-

portion, the third term of the proportion is always like the answer (the reason for this is more fully shown below). Only one of the elements must be considered at a time and the different quantities in this element must be arranged in the proportion as if the answer depended upon this element alone. For instance, if 8 men can earn $128 in 16 days, how much can 24 men earn in 6 days?

Here the different elements are dollars, men, and days. Now the question is, to find the number of dollars that can be earned by a certain number of men in a certain number of days, knowing a certain number of men can earn $128 in a given number of days. Therefore, dollars is the third term, because, as stated above, that number, or element, of the question which is like the answer is made the third term of the proportion.

Now take the other elements of the question. First take men and arrange the proportion as if the answer depended upon men only, saying, if 8 men can earn $128, how many dollars can 24 men earn? More. Therefore, 24 is the second term of the proportion and 8 is the first term, and as we know 128 to be the third term we have:

$$8 : 24 :: 128$$

Now take the next element in the question, which is days, and arrange in the proportion, the different quantities of this element as if the answer depended on it only, saying, if $128 can be earned in 16 days, how many can be earned in 6 days? Less will be earned in 6 than in 16 days, consequently 6 is the second term of the proportion in arranging this element. Thus:

$$16 : 6 ::$$

Now arrange the different elements as follows, placing

the first and second term of each element under the first and second term of the other. Thus:

8: 24:: \$128: the answer \$144
16: 6::

Now find the continued product of the second and third terms by multiplying $128 \times 24 \times 6$ and divide the product by the continued product of the first terms, that is, 8×16, and the quotient is the required answer.

Then: $$\frac{6 \times 24 \times 128}{16 \times 8} = \frac{18432}{128)18432(144\ \textit{Ans.}}$$

```
128)18432(144 Ans.
    128
     563
     512
      512
      512
```

EXAMPLE. If 4 horses eat 21 bushels of grain in 12 days, how many bushels will last 16 horses 24 days?

4: 16::
12: 24:: 21: answer 168 bushels

$$\frac{16 \times 24 \times 21}{4 \times 12} = \frac{8064}{48} = 168 \text{ bushels. } \textit{Ans.}$$

As the answer is in bushels, we make the 21 bushels the third term. If the answer depended only on the number of horses, it would be larger than the third term, as 16 horses will eat more than 4 horses. Then 16 is the second term and 4 the first term, and if the answer depended only on the number of days, it would also be larger than the answer, because, if 21 bushels are eaten in 12 days, a greater number of bushels will be eaten in 24 days. Hence, the second ratio, 12: 24. Then, as before, we divide the product of the two second terms

multiplied by the third terms by the product of the two first terms, and the quotient is the required answer.

EXAMPLE. If 8 horses mow a field of 128 acres in 16 days, how many acres will 24 horses mow in 6 days?

Here the different elements are horses, acres, and days, and the proposition is to find the number of acres that can be mowed by 24 horses in 6 days. If a given number of acres can be mowed by 8 horses in a given number of days, acres then is the third term of the proportion, because it is like the answer. Now take the other elements in the proportion and arrange them in the proportion as if the answer depended upon the element taken only.

We will first take horses and inquire, if 8 horses can mow 128 acres in 16 days, how many acres will 24 horses mow? 24 horses will mow more, therefore 24 is the second term in the proportion, and 8 is the first term. Thus:

$$8 : 24 :: 128$$
$$16 : 6$$
$$\frac{24 \times 6 \times 128}{8 \times 16} = \frac{18432}{128} = 144. \quad \textit{Ans.}$$

Now take the next element in the proportion, which is days, and inquire how many acres can be mowed in 6 days, if 128 acres can be mowed in 16 days; and as less can be mowed in 6 days than in 16 days, 6 is the second term of the proportion and consequently 16 is the first term, the terms being arranged in the proportion as if the answer depended upon days only, as shown above. Then divide the product of the second and third terms ($24 \times 6 \times 128$) by the product of the first terms (8×16), and the quotient is the answer, showing the number of acres that can be mowed by 24 horses in 6 days, if 128 acres can be mowed in 16 days by 8 horses.

Then, in short, the rule to be followed when working out proportion by the process of compound proportion:

First. Make that number which is like the answer (same denomination) always the third term.

Second. Then take any two of the remaining numbers of the same denomination and consider whether the answer, if depending on them alone, would be greater or less than the third term, and arrange the numbers accordingly.

Third. Then take any two of the other numbers of like denomination and arrange them as before, as if the answer depended upon them only, and so on until all are used.

Fourth. Then divide the product of the second terms, multiplied by the third term by the product of the first terms, and the quotient is the required answer.

Examples for Exercise

1. If 15 men can build a house in 60 days by working 15 hours per day, how long will it take 20 men to build the house if they work 10 hours per day?

$$20 : 15 :: 60$$
$$10 : 15 ::$$
$$\frac{15 \times 15 \times 60}{20 \times 10} = \frac{13500}{200} = 62\tfrac{1}{2} \text{ days.}$$

2. If 30 horses eat 12 tons of hay in 3 months, how much hay will 15 horses eat in 8 months?

$$30 : 15 :: 12$$
$$3 : 8$$
$$\frac{15 \times 8 \times 12}{30 \times 3} = \frac{1440}{90} \text{ 16 tons.}$$

3. If 10 men earn $120 in 7 days, how much will 7 men earn in 4 days? *Ans.* $48.

4. If 15 men can plow 360 acres in 8 weeks, how many acres can 27 men plow in 6 weeks? *Ans.* 486 acres.

5. If 20 boys and 15 men can earn $300 in 12 weeks, how many dollars will 20 boys and 5 men earn in 9 weeks? *Ans.* $75.

6. If the interest on $200 is $10 for 12 months, what will be the interest on $1200 for 8 months? *Ans.* $40.

7. If it takes $200 12 months to make $10, how long will it take $1200 to make $40? *Ans.* 8 months.

8. How many dollars can 12 men earn in 14 days if 7 men can earn $67 in 10 days? *Ans.* $160.8.

9. If a man walks 200 miles in 30 days by walking 9 hours per day, how many miles will he walk in 35 days if he walks 8 hours each day? *Ans.* $207\frac{1}{27}$ miles.

10. How many days of 8 hours will it take a man to walk 207 miles if he can walk 200 miles in 30 days by walking 9 hours per day? *Ans.* $34\frac{49}{160}$ days.

INTEREST

In order to perform examples coming under the head of this chapter, it will be necessary to know the names of the different terms used, and their meanings.

By interest is generally understood the payment, or the sum paid for the use of money.

If John hires from William $100 for one year, and pays William at the end of that time $105, he would be paying interest on the money lent him.

That which is lent is called the principal, or base, and the sum paid for the use of it is called the interest, or percentage, and the specific rate charged for the use of the money is called the rate per cent ("per centum").

Percentage and per cent are both derived from the Latin words per and centum, which means by the hun-

dred or hundredths. Thus, 5 per cent means five one-hundredths ($\frac{5}{100}$) and 12 per cent means twelve one-hundredths ($\frac{12}{100}$).

Then, if an article is bought for $100 and sold for $103, the gain is 3 per cent, because $3 is three one-hundredths of the original cost.

Again, if an article is bought for $100 and sold for $97, the loss is 3 per cent.

The sign % is used for the words per cent. Thus, 5% means 5 per cent, and 3% means 3 per cent.

Following are examples with rules for performing operations in interest. The first set of examples shows how the percentage is obtained when the principal and rate per cent are given. The second set of examples shows how the rate per cent is obtained when the principal and percentage are given, and the third set of examples shows how the principal is found when the rate and percentage are given.

Examples Showing how the Percentage is Obtained

Example. What is 3% of $12?

Process. Multiply the principal by the rate per cent.

Thus:

$$\begin{array}{r} \$12 \\ .03 \\ \hline .36 \text{ cents} \end{array}$$

Example. What is 5% of $75?

Thus:

$$\begin{array}{r} \$75 \\ .05 \\ \hline \$3.75 \end{array}$$

Example. What is 8% of 400?

$$\begin{array}{r} \$400 \\ .08 \\ \hline \$32.00 \end{array}$$

Example. What is 7% of 126 yards?

$$\begin{array}{r} 126 \\ .07 \\ \hline 8.82 \text{ yards} \end{array}$$

Examples for Exercise

1. What is 5% of \$350? *Ans.* \$17.50.
2. What is 7% of \$72? *Ans.* \$5.04.
3. What is 12% of \$100? *Ans.* \$12.
4. What is 6% of 60 yards? *Ans.* 3.60 yards.
5. What is 6% of 36 inches? *Ans.* 2.16 inches.
6. What is 12% of 12 hours? *Ans.* 1.44 hours.
7. What is 8% of \$500? *Ans.* \$40.
8. What is 10% of \$1000? *Ans.* \$100.

Examples Showing how the Rate Per Cent is Obtained when the Principal and Percentage are Given

Example. What per cent of \$36 is \$9?

Process. Divide the percentage by the principal, extending the division to hundredths. Thus:

$$\begin{array}{l} 36)9.0(0.25 = 25\% \\ \quad\ \ 72 \\ \quad\ \ \overline{180} \\ \quad\ \ \underline{180} \end{array}$$

EXAMPLE. What per cent of 21 miles is 11? Thus:

$$\begin{array}{l} 21)11.0(0.52\tfrac{8}{21} = 52\tfrac{8}{21}\% \\ \quad\ \ \underline{105} \\ \qquad\ 50 \\ \qquad\ \underline{42} \\ \qquad\ \tfrac{8}{21} \end{array}$$

EXAMPLE. What per cent of $50 is $25?

$$\begin{array}{l} 50)25.0(0.50 = 50\% \\ \quad\ \ \underline{250} \\ \qquad\ \ 0 \end{array}$$

EXAMPLE. What per cent of $100 is $45?

$$\begin{array}{l} 100)45.0(0.45 = 45\% \quad \textit{Ans.} \\ \qquad\ \underline{400} \\ \qquad\ \ 500 \\ \qquad\ \ \underline{500} \end{array}$$

EXAMPLE. What per cent of 350 bushels is 75 bushels? Thus:

$$\begin{array}{l} 350)75.0(0.21\tfrac{3}{7} = 21\tfrac{3}{7}\% \\ \qquad\ \underline{700} \\ \qquad\ \ 500 \\ \qquad\ \ \underline{350} \\ \qquad\ \ \dfrac{150}{350} = \dfrac{15}{35} = \dfrac{3}{7} \end{array}$$

EXAMPLE. What per cent of $256 is $36?

$$\begin{array}{l} 256)36.0(0.10\tfrac{5}{32} = 10\tfrac{5}{32}\% \\ \qquad\ \underline{256} \\ \qquad\ \ \dfrac{40}{256} = \dfrac{20}{128} = \dfrac{5}{32} \end{array}$$

EXAMPLE. What per cent of \$105 is \$100? Thus:

$$
\begin{array}{r}
105)100.0(0.94\tfrac{2}{7}\% \quad \textit{Ans.} \\
\underline{945} \\
550 \\
\underline{420} \\
\dfrac{30}{105} = \dfrac{2}{7}
\end{array}
$$

EXAMPLES FOR EXERCISE

1. What per cent of \$365.50 is 346? *Ans.* $94\frac{486}{731}\%$.
2. What per cent of \$293 is 67? *Ans.* $22\frac{254}{293}\%$.
3. What per cent of \$76 is 39? *Ans.* $51\frac{6}{19}\%$.
4. What per cent of 367 is 38? *Ans.* $10\frac{130}{367}\%$
5. What per cent of 245 is 103? *Ans.* $42\frac{2}{49}\%$
6. What per cent of \$5000 is \$500? *Ans.* 10%.
7. What per cent of 45 tons is 5 tons? *Ans.* $11\frac{1}{9}\%$.
8. What per cent of \$367.95 is \$37? *Ans.* $10\frac{410}{7359}\%$.

EXAMPLES SHOWING HOW THE PRINCIPAL IS FOUND, WHEN THE RATE PER CENT AND PERCENTAGE ARE GIVEN

EXAMPLE. \$75 is 5% of how much money?

PROCESS. Divide the rate per cent into 100 and multiply the percentage by the quotient, and the product obtained is the required answer.

$$
\begin{array}{lr}
\text{Thus} & 5)\underline{100} \\
 & 20 \\
\text{Then} & \$75 \\
 & \underline{20} \\
 & \$1500 \quad \textit{Ans.}
\end{array}
$$

EXAMPLE. 12 is 40% of what number?

$$\begin{array}{r|l} 40)\,100\,(2\frac{1}{2} & \\ 80 & \\ \hline \frac{20}{40} = \frac{1}{2} & \end{array}$$

$$\begin{array}{ll} \text{Then} & 12 \\ & \underline{2\frac{1}{2}} \\ & 24 \\ & \underline{6} \\ & 30 \quad \textit{Ans.} \end{array}$$

EXAMPLE. 40 is 12% of what number?

$$\begin{array}{r|l} 12)\,100\,(8\frac{1}{3} & \\ 96 & \\ \hline \frac{4}{12} = \frac{1}{3} & \end{array}$$

$$\begin{array}{ll} \text{Then} & 40 \\ & \underline{8\frac{1}{3}} \\ & 320 \\ & \underline{13\frac{1}{3}} \\ & 333\frac{1}{3} \quad \textit{Ans.} \end{array}$$

EXAMPLES FOR EXERCISE

1. \$2780 is 25% of how much? *Ans.* \$11.120.
2. \$372 is 6% of how much money? *Ans.* \$6.200.
3. 79 yards is 7% of how many yards? *Ans.* 1.128$\frac{4}{7}$ yards.
4. 32 bushels is 7% of how many bushels? *Ans.* 457$\frac{1}{7}$ bushels.
5. 28 is 5% of what number? *Ans.* 560.
6. 100 is 10% of what number? *Ans.* 1000.
7. What number is 100 10% of? *Ans.* 1000.
8. What number is 250 16% of? *Ans.* 1562$\frac{1}{2}$.
9. 12 inches is 6% of how many inches? *Ans.* 200 inches.

INVOLUTION

Involution is the raising a number (called the root) to any power. The powers of a number are its square, cube, fourth power, fifth power, etc.

$3 \times 3 = 9$. 9 is the square or second power of 3.

$3 \times 3 \times 3 = 27$. 27 is the cube, or third power of 3.

$3 \times 3 \times 3 \times 3 = 81$. 81 is the fourth power of 3.

Hence the second, third, fourth, fifth, sixth, etc., power is found by multiplying the number by itself 2 times, 3 times, 4 times, as the case may be.

The second power of a number is called its square, the third power is called the cube, and the fourth, fifth sixth, etc., powers are called the fourth, fifth, sixth, etc., powers. Then, to square a number, multiply it by itself.

Example. What is the square of 12 (written 12^2)?

$$\begin{array}{r} 12 \\ \underline{12} \\ 144 \end{array} \quad \textit{Ans.}$$

And to cube a number, multiply the square of the number by itself again; that is, multiply the number by itself 3 times.

Example. What is the cube of 12 (written 12^3)?

$$\begin{array}{r} 12 \\ \underline{12} \\ 144 \\ \underline{12} \\ 1728 \end{array} \quad \textit{Ans.}$$

Example. What is the sixth power of 12 (written 12^6)?

```
     12
     12
    ---
    144 square
     12
   ----
   1728 cube
     12
  -----
  20736 fourth power
     12
 ------
 248832 fifth power
     12
-------
2985984 sixth power
```

EVOLUTION

Evolution is the process of finding the "root" when any power of a number is given, and is the reverse of Involution.

There are only two cases where this is of much consequence: the finding the square root of a number and finding the cube root.

Square Root

To find the square root of a number is to find one of the two equal factors which produce it.

Example. Find the square root of 589824. Thus:

```
      58,98,24(768   Ans.
      49
      ---
  146)998
      876
      -----
 1528)12224
      12224
      -----
```

Process. Mark the figures off in two, from right to left, beginning, as we did in the above example, with the

last figure, 4; count two figures and mark the second, as shown, count two more and mark the figure, and so on till there are no more figures; then take the figure, or figures, to the left of the last dot, in this case 58, and find what number multiplied by itself will give 58. There is no number that will do so exactly, for $7 \times 7 = 49$ is too small, and $8 \times 8 = 64$ is too large. We take the one that is too small and place it in the quotient, and place its square, 49, under the 58, subtract and bring down the next two figures, 98. To get the divisor, multiply the quotient 7 by $2 = 14$, place the 14 in the divisor and say 14 into 99 goes 6 times, place the 6 after the 7 in the quotient and also after the 4 of the divisor; multiply the 146, now in the divisor, by the 6 in the quotient and place the product, 876, under the 998; subtract and bring down the next two figures, 24. To get the next divisor, multiply 76 by $2 = 152$, see how often 152 goes into 1222, which is eight times, place the 8 in the quotient after the 76 and in the divisor after the 2; multiply now the divisor 1528 by 8, and place the product under the 12224, then subtract.

Example. Find the square root of 835. Thus:

$$\begin{array}{rr}
 & 8{,}35(21.58 \quad \textit{Ans.} \\
 & \underline{4} \\
41) & 435 \\
 & \underline{41} \\
425) & 2500 \\
 & \underline{2125} \\
4308) & 37500 \\
 & 34464
\end{array}$$

We proceed as before till we get to the remainder, 25, and we see it is not a perfect square; we wish the root to be taken to two or three places of decimals; there are

no figures to bring down, therefore bring down two cyphers and proceed as in first example; to the remainder attach two more cyphers and proceed as before, by attaching two cyphers to the remainder. In this way it may be carried to any number of decimal places.

EXAMPLE. Find the square root of 688.0625.

Note this is a decimal quantity. In all such cases, instead of counting two from right to left, as in the preceding examples, we begin at the decimal point and count two toward the left and toward the right; we proceed then as in the other examples. Thus:

```
        6,88.06,25(26.23   Ans.
        4
     46)288
        276
    522) 1206
         1044
   5243)  16225
          15729
```

EXAMPLE. What is the square root of 17640.73205?

Thus:

```
          1,76,40.73,20,5(132.818   Ans.
          1
      23)  76
           69
     262)   740
            524
    2648)   21673
            21184
   26561)     48920
              26561
  265628)     2235950
              2125024
```

Notice in this example the last figure is 5; always bring down two figures at a time, therefore bring down 50.

EXAMPLES FOR EXERCISE

1. Find the square root of 186624. *Ans.* 432.
2. Find the square root of 3998.64. *Ans.* 63.234.
3. Find the square root of 49.434961. *Ans.* 7.034.
4. Find the square root of 588.0625. *Ans.* 24.25.
5. Find the square root of 7986.57246. *Ans.* 89.367.

CUBE ROOT

To find the cube root of a number is to find one of the three equal factors which produce it. The process of extracting from a given number a certain specific number, which, when multiplied by itself three times, will equal the given number.

EXAMPLE. Extract the cube root of 46656.

PROCESS. Mark off three figures from the right, and there are 46 left. Find what number cubed will come to 46, or less than it. Now 2 cubed = 8, that is $(2 \times 2 \times 2 = 8)$, 3 cubed = 27, 4 cubed = 64, so the number we need must be somewhat more than 3 but less than 4, we therefore take the 3. Arrange it as follows:

$$\begin{array}{rl} 46{,}656(36 & \quad \textit{Ans.} \\ \underline{27} & \\ 96)2700)19656 & \\ \underline{576)} & \\ 3276)\underline{19656} & \end{array}$$

The three cubed is 27; put the 27 underneath the 46 and subtract; the remainder is 19. Bring down the next three figures (656); multiply now the figures in the quotient by 3 and put the product well out to the left.

Here it is $3 \times 3 = 9$. Put this 9 well out to the left, as shown; next multiply this 9 by the quotient figure 3, and place the result, 27, to the right of where the 9 is placed, and always put two cyphers after the product, as in example.

This 2700 is called the "trial divisor." See how often it will go into 19656; it will go 7 times, but so close that we had better take 6. Put this 6 in the quotient after the 3 and also after the figure 9 on the left, making 96; then multiply the 96 by the new quotient figure $6 = 576$, which place under the 2700; add them together and the sum, 3276, is the correct divisor; multiply this correct divisor by the quotient figure 6 and place the product as shown; subtract, there being no remainder.

The cube root of 46656 is found to be 36.

Example. Find the cube root of 146863664576. Thus:

		146,863,664,576(5276
Column 1	Column 2	125
152	7500	)21863
	304	
	7804	15608
1567	811200	) 6255664
	10969	
	822169	5755183
15816	83318700	) 500481576
	94896	
	83413596	) 500481576

Process. Mark them off in threes from right to left, and there are 146 to the left; 5, which placed in the quotient, is found to be the next less cube of 146, and the cube of 5 is 125; place the 125 under the 146 and subtract, and bring down the next three figures.

Multiply the 5 by 3 = 15; put this well out to the left.

Multiply the 15 by the 5 = 75. Put this down with two cyphers annexed = 7500, for the "first trial divisor;" it goes twice. Put the 2 in the quotient, also place it on the right of the 15 on the left; multiply 152 by 2 = 304, which place under the trial divisor, 7500; add them together and the sum 7804 is the "real divisor"; multiply this by the quotient figure 2 = 15608, which put down and subtract, and on the right of the difference, 6255, place the next three figures, 664.

To find the third figure of the answer, multiply the 52 in the quotient by 3 = 156. Place this well out to the left (column 1). Look at the middle column (column 2), and you will see the numbers 304 and 7804; add these together and to their sum add the square of the last figure in the quotient(which is 2 in this case) and the square of 2 is 2 × 2 = 4.

$$\begin{array}{r} 304 \\ 7804 \\ 4 \\ \hline 8112 \end{array}$$

and this number, with two cyphers annexed, equals 811200, is the new "trial divisor;" it goes 7 times. Put the 7 in the quotient and also after the 156 in column 1; now multiply 1567 by 7 = 10969, and put this under the trial divisor; add them together and the sum is the correct divisor, and is 822169, which multiplied by 7, and the product put down and subtracted, leaves 500481, on the right of which place the next three figures, 576.

To find the fourth figure of the answer: Multiply the quotient 527 by 3 = 1581, which place in column 1, well to the left. Now look at the middle column (column 2) and add together the 10969, the 822169, and the square

of the last figure in the quotient in this case, the square of 7, equals 49.

$$\begin{array}{r} 10969 \\ 822169 \\ 49 \\ \hline 833187 \end{array}$$

This number with two cyphers after it is the new "trial divisor;" it goes 6 times. Put the 6 in the quotient and also after the 1581 in column 1; now multiply this 15816 by the 6 in the quotient = 94896, which place under the trial divisor; add them together and multiply the sum by the 6. Put the product 500481576 down, subtract, — there is no remainder. Therefore, the cube root of the given number 146863664576 is 5276.

Following is another method of extracting the cube root which may, perhaps, be considered simpler.

Find the cube root of 1728.

$$\begin{array}{rrl} & & 1,728(12 \quad \textit{Ans.} \\ & & 1 \\ \hline 3 \times (10)^2 = & 300) & 728 \\ 3 \times 10 \times 2 = & 60 & \\ 2^2 = & 4 & \\ \hline & 364) & 728 \end{array}$$

The advantage of this method is that when the pupil has mastered the workings of the first figure of the quotient, the rest of the sum is at his command, as the process is the same for any number of figures, the same for twenty as for two.

Process Explaining how Examples are Performed by the Above Method

The number 1728 was first marked off into quantities of three figures as before, and selecting the next lowest

cube for the first period, in this case 1, which place in quotient and divisor, $1^3 = 1$, which place under the 1 in the dividend. Now bring down next three figures (728). Take now the number in quotient (in this case 1) add a nought to it, making it 10; this always square and multiply by the constant 3. Thus $3 \times (10^2) = 300$; this forms a trial divisor. For the next line, still use the 3 which now multiply by 10 (not 10^2 this time), multiply product thus obtained by that figure in quotient, obtained from the trial divisor; thus $3 \times 10 \times 2 = 60$, which place under the 300. For the third line simply square the number obtained by the trial divisor in this case $2^2 = 4$, which place under the 60 then add all quotients together.

$$\begin{array}{rr}
3 \times 10^2 = & 300 \\
3 \times 10 \times 2 = & 60 \\
2^3 = & \underline{\quad 4} \\
 & 364 = \text{divisor.}
\end{array}$$

EXAMPLE. Find the cube root of 2438569736.

$$\begin{array}{rl}
 & 2,438,569,736(1346 \quad \textit{Ans.} \\
 & \underline{1} \\
3 \times 10^2 = & 300)1438 \\
3 \times 10 \times 3 = & \quad 90 \\
3^2 = & \quad \underline{9} \\
 & 399)1197 \\
3 \times (130^2) = & 50700)\ 241569 \\
3 \times 130 \times 4 = & \quad 1560 \\
4^2 = & \quad \underline{16} \\
 & 52276)\ 209104 \\
3 \times (1340^2) = & 5386800)\ \ 32465736 \\
3 \times 1340 \times 3 = & \quad 24120 \\
6^2 = & \quad \underline{36} \\
 & 5410956)\ \ 32465736
\end{array}$$

Examples for Exercise

Find the cube root of the following numbers:

1. 16934.994432. *Ans.* 25.68.
2. 134217728. *Ans.* 512.
3. 80677568161. *Ans.* 4321.
4. 15069223. *Ans.* 247.

PART II

ARITHMETICAL SIGNS AND CHARACTERS AND EXPLANATION OF FORMULA

ARITHMETICAL SIGNS

By a knowledge of the meaning of the different arithmetical signs and by the proper use of same, we are enabled to perform arithmetical problems in a brief way.

The sign $+$ reads "plus," and "more," and means that the number after it is to be added to the number before it; thus, $3 + 5$ are 8.

The sign $-$ reads "minus," "less," signifying subtract, and means that the number after it is to be subtracted from the number before it; thus, $5 - 3$ leaves 2.

The sign $\times$ reads "multiply by," and means the number before it is multiplied by the number after it; thus, 2×2 are 4.

The sign $\div$ reads "divide by," and means that the number before it is to be divided by the number after it; thus, $4 \div 2$ is 2.

The sign : reads "divide by," also, and means that the number after it is to be divided by the number before it; thus, $4 : 2$ is 2.

The sign $\frac{18}{3}$ reads divided by 3, and is the same thing as $18 \div 3$ equals 6.

The sign $=$ reads "equality," or "equal to," and means that the quantity after it is equal to or of the same value as the quantity before it; thus $3 + 6 = 9$, or $6 - 3 = 3$, or $6 + 2 \times 2 = 16$.

The sign 5^2 reads 5 squared, and means that 5 is to be multiplied by itself; thus, $5 \times 5 = 25$; then 25 is called the square of 5. And 5^3 reads, 5 cubed, $5 \times 5 \times 5 = 125$, and 5^4 means that 5 is to be multiplied by itself four times.

The sign $\sqrt{}$ reads the "square root," and means that the square root of the number alongside it is to be considered; thus, $\sqrt{36}$ reads the square root of 36 and means that number which, when multiplied by itself, gives 36; thus, $6 \times 6 = 36$, hence 6 is called the square root of 36. Sometimes the sign of square root is represented thus, $\sqrt[2]{36}$, which reads what number, when squared, is equal to the number 36.

The sign $\sqrt[3]{}$ reads the "cube root" and means that the cube root of the number alongside it is to be considered; thus, $\sqrt[3]{216}$ reads the cube root of 216 and means that number which, when multiplied by itself three times, gives 216; thus, $6 \times 6 \times 6 = 216$, hence 6 is the cube root of 216.

Example. $5 \times \sqrt[3]{216}$ is what? The question here is what is the product of 5 multiplied by the cube root of 216, and as the cube root of 216 is 6, then $5 \times 6 = 30$. *Ans.*

The sign $\sim$ reads the difference between and means that the less number, whether before or after it, is to be subtracted from the greater number; thus, $5 \sim 2 = 3$, and $2 \sim 5 = 3$.

The sign () is called "brackets." Brackets are of various shapes, thus: ( ), { }, [ ].

Where brackets are used it is meant that all the quantities within each set of brackets are to be put together first and treated as a whole; thus $(12 + 4 - 3) - (12 + 3 - 7)$ means that the 4 is to be added to $12 = 16$, and that 3 is to be subtracted; therefore, $16 - 3 = 13$, hence the quantities in the first set of brackets, when put together, become 13.

Take now the quantities between the next set of brackets, which treat in the same way; thus, $12 + 3 = 15 - 7 = 8$. Here we have 8 as a result of putting the

quantities together as directed by the signs. The sum is now $13 - 8 = 5$. *Ans.*

Sometimes, instead of brackets, a line called a vinculum is drawn over the expression which is to be treated as a whole. Thus, $\overline{6 \times 4} + \overline{3 \times 2} + 1$ means that the product of $6 \times 4 = 24$ is to be added to the product of $3 \times 2 = 6$, and to the sum of the products is to be added 1. Thus:

$$\begin{array}{r} 24 \\ 6 \\ 1 \\ \hline 31 \end{array} \quad \textit{Ans.}$$

Thus, in the above example, $\overline{6 \times 4} + \overline{3 \times 2} + 1$ is equivalent to $(6 \times 4) + (3 \times 2) + 1$.

The sign $\because$ reads "because," or "since."

The sign $\therefore$ reads "therefore," or "hence."

The sign $>$ indicates that the number which is before it is greater than the number which follows it.

The sign $<$ indicates that the number before it is less than the number which follows it.

The sign $\neq$ reads, or stands, for the words "is not equal to."

The sign $\nless$ stands for the words "is not less than."

The sign $\ngtr$ stands for the words "is not greater than."

Examples on the Use of the Addition Sign

The addition sign requires little notice, because when placed before a number it indicates that it is to be "added" to what has gone before. Thus, $3 + 9$ means that 9 is to be added to 3, and $3 + 9 + 2$ means that 9 is to be added to 3 and then 2 added to the result. Thus, in addition, the order of performing operations is from left to right.

Examples for Exercise

What is the sum of $2 + 6 + 9$? *Ans.* 17.
What is the sum of $15 + 3 + 1$? *Ans.* 19.
What is the sum of $7 + 9 + 6 + 8$? *Ans.* 30.
What is the sum of $8 + 2 + 3 + 1$? *Ans.* 14.
What is the sum of $6 + 0 + 3 + 5 + 7$? *Ans.* 21.

Examples on the Use of the Minus Sign

This sign requires little notice also, because when placed before a number it indicates that it is to be subtracted from what has gone before. Thus, $4 - 2$ means that 2 is to be subtracted from 4, and $16 - 4 - 3$ means that 4 is to be subtracted from 16 and then 3 is to be subtracted from the result. Thus, $16 - 4 = 12$, and $12 - 3 = 9$. *Ans.*

Then in subtraction, the order of performing operations is from left to right, as it was in addition.

Examples for Exercise

What is the result of $25 - 3 - 4$? *Ans.* 18.
What is the result of $19 - 2 - 10$? *Ans.* 7.
What is the result of $16 - 8 - 8$? *Ans.* 0.
What is the result of $100 - 50 - 25$? *Ans.* 25.
What is the result of $300 - 50 - 100 - 100$? *Ans.* 50.

Examples Performed where the Addition and Minus Signs are Involved

Note when the first term of any quantity has no sign before it the + (plus) sign is always understood to be there.

Example. What is the sum of $12 + 4 - 2 + 7 - 4$.

Here we add together all those terms which have the + sign actually before them as $+ 4 + 7$, and the term

which is understood to have the + sign before it, although the sign is not put down; in this case it is the 12. Then 12, 4, 7 added together make 23, and − 2 and − 4 added together make −6. The sum then becomes 23 − 6 = 17. *Ans.*

EXAMPLE. Find the sum of 24 − 16 + 4 − 7 + 4.

$$\begin{array}{lll} \text{Thus} & +24+4+4= & +32 \\ \text{And} & -16 \text{ and } -7= & \underline{-23} \\ & & \quad 9 \quad \textit{Ans.} \end{array}$$

EXAMPLE. What does the following come to?

$$-6+3+2-5$$

Proceed as before by adding together all those terms which actually have the + sign before them, and then add together all those signs having the − sign; subtract, then, the smaller from the larger, but put before the remainder the same sign as that of the larger quantity. The above example, then, will be solved thus:

$+3+2=5$ sum of terms having the + sign

$-6-5=-11$ sum of terms having the − sign

$$\begin{array}{rr} \text{Then} & -11 \\ & +\underline{\ \ 5} \\ & -\ \ 6 \quad \textit{Ans.} \end{array}$$

EXAMPLE. − 8 + 12 + 2 − 9 + 3 − 8 + 2 − 17 comes to what?

$$\begin{array}{lrr} \text{Thus} & -8 & +12 \\ & -9 & +2 \\ & -8 & +3 \\ & -\underline{17} & +\underline{2} \\ & -42 & +19 \end{array}$$

$$\begin{array}{lr} \text{Then} & -42 \\ & +\underline{19} \\ & -23 \quad \textit{Ans.} \end{array}$$

Note that the answers of both above examples have the − sign before them, because the sum of the quantities after the − signs are the larger.

Examples for Exercise

What do the following come to?

1. $8 - 12 - 2 + 9 - 3 + 8 - 2 + 17$. *Ans.* $+ 23$.
2. $- 4 + 3 - 7 - 8 + 2$. *Ans.* $- 14$.
3. $5 - 17 + 3 + 2$. *Ans.* $- 7$.
4. $25 - 6 - 2 + 7$. *Ans.* $+ 24$.
5. $10 - 25 + 3 + 15 - 17$. *Ans.* $- 14$.

Examples Showing how Brackets ( ) are Used

Example. $- 3 + 4 + 6 - (5 + 6) + 8 - (9 - 3) + (14 - 4 - 4)$ is equal to what?

Process. Get rid of all the brackets first by putting the quantities within each set of brackets together so that they become a single number. Then to solve the above problem we proceed to deal with the terms inside each bracket first.

Thus

$$(5 + 6) = 11 \quad (9 - 3) = 6 \quad (14 - 4 - 4) = 6$$

Hence

$$- 3 + 4 + 6 - (5 + 6) + 8 - (9 - 3) + (14 - 4 - 4)$$

Becomes

$$- 3 + 4 + 6 - 11 + 8 - 6 + 6$$

Add now all the + signs together and all the − signs together, subtract the larger from the smaller and the result is the required answer.

$$\begin{array}{lrr@{\qquad\qquad}r}
\text{Thus} & + & 4 & -\ \ 3 \\
 & + & 6 & -\ 11 \\
 & + & \underline{6} & -\ \ \underline{6} \\
 & + & \underline{6} & -\ 20 \\
 & + & 24 & \\
 & - & \underline{20} & \\
 & + & 4 \quad \textit{Ans.} &
\end{array}$$

Example. $7 - 8 + 6 - (5 - 6 + 3) + 9 + (9 - 3 + 2 - 6 + 7)$ is equal to what?

Thus

$$7 - 8 + 6 - (5 - 6 + 3) + 9 + (9 - 3 + 2 - 6 + 7)$$

Equals

$$7 - 8 + 6 - 2 + 9 + 9$$

Adding all the $+$ signs together we get 31
Adding all the $-$ signs together we get 10

Thus $31 - 10 = 21$ *Ans.*

Note. When no sign is between the quantity outside the bracket and the bracket, it means that the quantity within the bracket is to be multiplied by the quantity outside.

Example. $3(4 - 2 + 3) - 2 + 6$ is equal to what?

Here outside the brackets is 3, having no sign between it and the bracket, which means that after reducing the numbers within the brackets to a single number we multiply it by 3.

Thus $3\ (4 - 2 + 3) = 5$ multiplied by $3 = 15$
Hence $3\ (4 - 2 + 3) - 2 + 6$
Equals $15 - 2 + 6$

Adding all the plus quantities together, and all the minus ones separately, we get, $21 - 2 = 19$ *Ans.*

EXAMPLE. $4(3 + 2 - 6 + 4) + 2(3 + 6 - 2)$ is equal to what?

Thus	$4(3 + 2 - 6 + 4) + 2(3 + 6 - 2)$
Becomes	$3 \times 4 + 7 \times 2$
Which is	$12 + 14$

Which added together is:

$$\begin{array}{r} 12 \\ \underline{14} \\ 26 \end{array} \quad \textit{Ans.}$$

EXAMPLES FOR EXERCISE

The following equals what?

1. $-2 + 12 + 3 - (9 + 4) + 3 - (7 - 5) + (6 - 2 + 7)$. *Ans.* 12.
2. $4(3 + 2 - 6 + 4) + 2(3 + 6 - 2)$. *Ans.* 26.
3. $4(3 + 2 - 6 + 4) - 2(3 + 6 - 2)$. *Ans.* -2
4. $3(4 - 2 + 3) + 2 - 6$. *Ans.* 11.
5. $-2 + 6 + 2 - (4 + 3) + 4 - (7 - 5) + (7 - 1 + 2)$. *Ans.* 9.

EXAMPLES ON THE PROPER USE OF THE MULTIPLICATION SIGN

The multiplication sign, $\times$, is placed between two numbers to indicate that the first number is to be multiplied by the second. Thus, 12×6 means that 12 is to be multiplied by 6; also $12 \times 6 \times 3$ means that 12 is to be multiplied by 6 and the result multiplied by 3. Sometimes the sign $\times$ is replaced by a point or dot which is placed in a line with the bottom of the quantities to be multiplied. Thus, $12 \times 6 \times 3$, and 12.6.3, mean the same thing, namely, that 12 is to be multiplied by 6 and the result by 3.

Because of the improper use of the multiplication sign

it causes more trouble than any of the other signs. For instance, in a quantity such as follows $7 + 2 \times 4$ we would be apt to say 7 and 2 are 9, which, multiplied by $4 = 36$. Now this would be wrong. The first step would be to multiply the 2 by 4 and then to the result add the 7.

Thus	$7 + 2 \times 4$
Becomes	$7 + 8$
Equals	15 *Ans.*

We learn, then, from the above, that the first step to take when the multiplication sign is involved, is to get rid of it in the manner shown. That is, always get rid of the multiplication sign first, unless brackets are used, in which case, we would get rid of all brackets first, and then dispose of the multiplication signs.

Example. $4 - 3 \times 2 + 6 \times 4 - 2 \times 3 + 8 \times 2$ is equal to what?

Thus	$4 - 3 \times 2 + 6 \times 4 - 2 \times 3 + 8 \times 2$
Becomes	$4 - 6 + 24 - 6 + 16$

Now put the terms together as in addition and subtraction, and we have $44 - 12 = 32$ *Ans.*

Examples. What does the following equal?

$$- 3 + 4 + 2 \times 6 \times 2 - 3 + 4 \times 6$$

Thus	$- 3 + 4 + 2 \times 6 \times 2 - 3 + 4 \times 6$
Becomes	$- 3 + 4 + 24 - 3 + 24$
	$+ 4 + 24 + 24 = + 52$
And	$- 3 + - 3 \quad = - \underline{6}$
	46 *Ans.*

Example. What is the following equal to?

$$24 - (32 - 15) + 3 \times (9 - 5)$$

Process. Get rid of all the brackets and then get rid of the multiplication signs.

The example, $24 - (32 - 15) + 3 \times (9 - 5)$, becomes $24 - 17 + 3 \times 4$. The brackets are here disposed of.

Now dispose of the multiplication sign and we have $24 - 17 + 12$.

Proceed now as in addition and subtraction.

$$\begin{array}{l} 24 \\ \underline{12} \\ 36 - 17 = 19 \quad \textit{Ans.} \end{array}$$

Examples for Exercise

Find the value of the following:

1. $6 + 4 \times (9 - 3) + 7 - 2 \times (45 - 41)$. *Ans.* ~~51~~. 29
2. $54 - (64 - 29) + 6 \times (18 - 5)$. *Ans.* 97.
3. $24 - (32 - 15) + 3 \times (9 - 5)$. *Ans.* 19.
4. $-3 + 4 + 2 \times 6 \times 2 - 3 + 4 \times 6$. *Ans.* 46.
5. $4 - 3 \times 2 + 6 \times 4 - 2 \times 3 + 8 \times 2$. *Ans.* 32.

Examples on the Use of the Division Sign

Example. $5 + 2 \times (7 - 2) - 4 - 8 \div (3 + 5)$ equals what number?

Process. First get rid of all the brackets; secondly, get rid of the multiplication and division signs, then proceed as in addition and subtraction.

Example. $5 + 2 \times (7 - 2) - 4 - 8 \div (3 + 5)$.

Brackets left out, $5 + 2 \times 5 - 4 - 8 \div 8$.

Multiplication and division signs done away with, $5 + 10 - 4 - 1$.

$$\begin{array}{rr} +5 + 10 = & +15 \\ -4 + -1 = & -\underline{5} \\ & 10 \quad \textit{Ans.} \end{array}$$

Example. $32 \div 4 \div 2$.

$$\begin{array}{r} \text{Thus } 4\underline{)32} \\ 2\underline{)8} \\ 4 \quad \textit{Ans.} \end{array}$$

EXAMPLE. $32 \div 4 + 2.$

$$\begin{array}{r} \text{Thus } 4\underline{)32} \\ 8 \\ \underline{2} \\ 10 \quad \textit{Ans.} \end{array}$$

EXAMPLE. What is $24 \div 6 + 4 - 2$ equal to?

$$\begin{array}{l} \text{Thus } 6\underline{)24} \\ \qquad\quad 4 \\ \qquad\quad \underline{4} \\ \qquad\quad 8 - 2 = 6 \quad \textit{Ans.} \end{array}$$

EXAMPLE. What does the following amount to?

$$(3 + 5) \times 6 - 2 \times (2 + 2) \div 4 - 5 + 10$$

$$\begin{array}{llll} \text{Thus } 8 \times 6 - 2 \times 4 \div 4 - 5 + 10 & & & \\ +\ 48 & -\ 2 & & \\ +\ \underline{10} & -\ \underline{5} & & \\ +\ 58 & -\ 7 & = 51 & \textit{Ans.} \end{array}$$

EXAMPLE. $2 \times 4 \div 2$ amounts to what?

$$8 \div 2 = 4 \quad \textit{Ans.}$$

Sometimes division is represented thus:

$$\frac{4 + 2}{6 - 4}$$

where one quantity is placed above another with a line between them. When thus represented the value of the top quantity is to be divided by the value of the bottom quantity. That is, in the above example the $4 + 2$ is to be divided by the $6 - 4$.

Thus $\dfrac{4 + 2 = 6}{6 - 4 = 2}$

Then $6 \div 2 = 3$ *Ans.*

Example. $\dfrac{5 + 4 \times 6}{2 + 3 \times 6}$ is equal to how many?

Thus $\dfrac{5 + 4 \times 6 = 29}{2 + 3 \times 6 = 20}$ (And)

Thus $29 \div 20 = 1\frac{9}{20}$ *Ans.*

Example. $3\,\dfrac{12 - 4 + (6 - 4)}{(6 - 4) + (16 - 8)}$

Such examples as the above sometimes cause trouble. Note that the 3 before the fraction is placed on the level of the division line, and in this position it indicates that the whole fraction is to be multiplied by it. It will be remembered, however, when multiplying a fraction by a whole number, that the numerator of the fraction is multiplied only. Then in the above example the top line only is multiplied by the 3.

$$\text{Thus: } 3\,\frac{12 - 4 + (6 - 4) = 8 + 2 = 10}{(6 - 4) + (16 - 8) = 2 + 8 = 10}$$

$$\text{Then } 3\,\frac{10}{10} = \frac{30}{10} = 3 \text{ } Ans.$$

The pupil would better now refer to vulgar fractions and become very familiar with the fact as there explained, that when multiplying a fraction by a whole number the numerator of the fraction is multiplied only.

Example. $3\,(12 - 4 + 6 - 4) \div (6 - 4 + 16 - 8)$ is equal to how many ?

Thus $3\,(12 - 4 + 6 - 4) \div (6 - 4 + 16 - 8)$

Becomes $10 \div 10$

3

$30 \div 10 = 3$ *Ans.*

It will be remembered, when no sign is placed between a quantity and a bracket, that the quantity within the bracket is to be multiplied by the quantity without. Therefore, after reducing the quantity in the first set of brackets to 10, we multiplied by 3 and then divide by the sum of the quantities within the next brackets.

The following example will impress this more fully upon the mind:

EXAMPLE. Find the value of $4 + 2\ (2 + 6) - 3 + 2\ (9 - 4)$, which is the same as $4 + 2 \times (2 + 6) - 3 + 2 \times (9 - 4)$.

$$\text{Hence}\quad 4 + 2 \times 8 - 3 + 2 \times 5$$
$$4 + 16 - 3 + 10$$

$$\begin{array}{r} 4 \\ 16 \\ 10 \\ \hline 30 \end{array} - 3 = 27 \quad \textit{Ans.}$$

EXAMPLES FOR EXERCISE

Find the value of:

1. $\dfrac{7 + 7 - (6 - 2)}{(5 - 2) + 3 - 1}$. *Ans.* 2.
2. $14 + 6 - (2 + 4) \div (6 + 8 - 12)$. *Ans.* 17.
3. $9 + 4 \times (7 - 3) - 8 - 16 \div (9 - 5)$. *Ans.* 13.
4. $3\ \dfrac{12 - 4 + (6 - 4)}{(6 - 4) + (16 - 8)}$. *Ans.* 3.

EXERCISES ON THE SIGNS REPRESENTING THE POWER OF NUMBERS, AS 4^2, 4^3, 4^4, ETC.

The powers of a number are its square, cube, fourth power, fifth power, etc.

Thus 4^2 is equal to $4 \times 4 = 16$
4^3 is equal to $4 \times 4 \times 4 = 64$
4^4 is equal to $4 \times 4 \times 4 \times 4 = 256$

Especial names are given to 4^2 and 4^3; they are called respectively, the square and cube of 4.

The small figure, or letter, placed above a quantity, to indicate the number of times that quantity is to be taken as a factor is called the "Index," or "Exponent."

Thus, 4^2 means that the factor 4 is to be taken 2 times and 2 is called the index. Therefore, always multiply the given number that number of times by itself, as indicated by the "Index," and the continued product is the required power. That is, 4 to the eighth power (4^8) is $4 \times 4 \times 4 \times 4 \times 4 \times 4 \times 4 \times 4 = 65536$

EXAMPLE. $4^2 + 6^3$ is equal to what?

$$\begin{aligned} 4^2 &= 16 \\ 6^3 &= \underline{216} \\ & 232 \quad \textit{Ans.} \end{aligned}$$

EXAMPLE. $4^3 - 3^3$ is equal to what?

$4^3 = 64$
$3^3 = 27$ Then $64 - 27 = 37$ *Ans.*

EXERCISES ON THE SIGN THAT REPRESENTS THE ROOTS OF NUMBERS $\sqrt{\ }$ AND $\sqrt[3]{\ }$ AND $\sqrt{\qquad}$

A number which, when squared, is equal to some specific number is called a "square root," and is represented by the symbol $\sqrt{\ }$ and sometimes $\sqrt[2]{\ }$. Thus 6 is $\sqrt{36}$, since $6^2 = 36$,

And a number which, when cubed, is equal to any specific number is called a "cube root," and is represented by the symbol $\sqrt[3]{\ }$. Thus 4 is $\sqrt[3]{64}$, since $4^3 = 64$.

The sign ($\sqrt{\ }$), which represents the root of numbers, was originally the first letter of the word *radix,* which word really means the source from which anything springs. The sign is now called the "radical sign," and the radical sign is common to all roots. Thus, when it is required to express the square root of a number or quantity, we simply place this sign before it, as $\sqrt{\ }$ 144, and when it is required to express the cube root of a number or quantity, the same sign is placed before the number with a 3 in the elbow, thus $\sqrt[3]{\ }$.

Sometimes a number composed of two or more terms is to have its root expressed. In all such cases, place the radical sign in front and draw a line over the numbers whose root is required as far as they extend.

For example, $\sqrt{3(4 + 2 + 3)}$ means that the square root of the sum of those numbers under the line is to be expressed, also $\sqrt{2 + 14}$ means that the square of the sum of the numbers underneath the line is required. Also $\sqrt[3]{2 + 6}$ expresses that the cube root of the sum of the numbers under the line is required.

Following is another way, which is not often used, for expressing that the root is required.

Thus, $16^{\frac{1}{2}}$ means that the square root of 16 is required. And $(2 + 14)^{\frac{1}{2}}$ means that the square root of the sum of the numbers within the brackets is required. Sometimes the power and root are combined, as $4^{\frac{3}{2}}$. This is read as the square root of 4 cubed. In all such cases the numerator figure represents the power, and the denominator figure represents the root. In the above example 4 cubed = 64 and the square root of 64 = 8.

Law of Signs in Multiplication

For those who are not acquainted with algebra it is difficult and very confusing to know how to *determine the sign* of the *product.* The rule by which the sign of the product is determined is called the "Law of Signs."

Rule 1. Plus and minus multiplied together always give minus.

Rule 2. Minus and minus multiplied together always give plus.

In other words, when multiplied together like signs give + and unlike signs give −. For example:

$$-3 \times +2 = -6$$

Here minus 3 is multiplied by plus 2 and the sign of the product 6 is a minus sign, thus − 6, product. Because unlike signs multiplied together give −. (Rule 1.)

Example. $8 + 4 - 3 \times (3 - 2 + 4)$ is equal to how much?

First gather together the numbers inside the brackets and we have

$$8 + 4 - 3 \times (3 - 2 + 4)$$

Becomes $\quad 8 + 4 - 3 \times +5$

When a number has no sign before it, *remember* that the + sign is always understood to be before it, hence the 3 in the brackets is + 3, which, when added to the + 4 = + 7, from which − 2 is subtracted, and we have + 5 left. Therefore, when the numbers inside the brackets are gathered up we have + 5, which is to be multiplied by − 3. The sum then is:

$$8 + 4 - 3 \times +5$$

$$8 + 4 - 15 = -3 \quad \textit{Ans.}$$

Example. What is the value of

$$8 + 14 - 6 \times (10 - 14 + 6)$$

Becomes $8 + 14 - 6 \times + 2$
Becomes $8 + 14 - 12$
Becomes $8 + 14 = 22 - 12 = 10$ *Ans.*

Example. What is the product of $- 6 \times - 6$?

Thus $- 6 \times - 6 = + 36$ *Ans.*

Here minus 6 is multiplied by minus 6 and the sign of the product is plus. Because like signs multiplied together give + (Rule 2).

Example. What is the product of $+ 6 \times + 6$?

$$+ 6 \times + 6 = + 36. \quad \textit{Ans.}$$

Example. $13 - 9 \times 4 - 11 \times (5 - 42 + 29)$ equals what ?

$$13 - 36 - 11 \times - 8$$

This is an example of Rule 2, being $- 11 \times - 8 = + 88$.

Hence $13 - 36 + 88 = 65$ *Ans.*

Example. What is the value of

$$32 \div 8 - 11 - 9 \times (32 - 71 + 29)$$
$$4 - 11 - 9 \times - 10$$

This again is an example of Rule 2, being minus 9 × minus 10. Thus $- 9 \times - 10 = + 90$. (Like signs give +.)

Hence $4 - 11 + 90 = 83$ *Ans.*

The + sign is not placed before the answer, 83, of the above example, because when no sign is before a quantity + is always understood to be there.

Law of Signs in Division

In division we have the same "Law of Signs" as in multiplication.

Unlike signs give $-$. (Rule 1.)

And like signs give $+$. (Rule 2.)

That is, if the signs of the dividend and divisor are unlike, the sign of the quotient is minus ($-$), and if the signs of the dividend and divisor are like signs, the sign of the quotient is plus ($+$).

For example: $-12 \div -4 = +3$ *Ans.*

The answer here is plus 3 because the sign of the dividend (-12) and the sign of the divisor (-4) are like signs, and like signs give $+$. (Rule 2.)

Example. $+12 \div +4 = +3$ *Ans.* (Rule 2.)

Example. $+15 \div -3 = -5$ *Ans.* (Rule 1.)

In the above example the quotient sign is minus, because the sign of the dividend and the sign of the divisor are unlike.

Example. $-16 \div +4 = -4$ *Ans.* (Rule 1.)

Example. $(9 \times 24 + 6) \div (4 + 2 \times 8 - 131)$.

$$216 + 6 \div 4 + 16 - 131$$
$$+222 \div -111$$

This is now an example of Rule 1.

$$+222 \div -111 = -2 \quad \textit{Ans.}$$

Miscellaneous Examples for Exercise

1. $42 \div 7 + 6 - 2$. *Ans.* 10.
2. $56 \div 4 - 3 \times 6 + 4$. *Ans.* 0.
3. $250 \div 10 + 4 - 2 \times (26 - 13)$. *Ans.* 3.
4. $(52 - 8.14) \times (8 + 4)$. *Ans.* 526.32.
5. $(52 - 8.14) \times 8 + 4$. *Ans.* 350.92.

6. $\dfrac{(42.4 - 12)^2 - 8 \times 4.}{64 - 23}$ *Ans.* 21.76.

7. What is the value of $(12 + 3)^3 - (21 - 4)^2$. *Ans.* 3014.

8. $\dfrac{(4.05)^2.}{(\frac{1}{8})^3}$ *Ans.* 8398.08.

9. $(6.012 + 0.050) \times (.070 \div \frac{1}{8})$. *Ans.* 3.395.

10. $(2.562 + 6.0002) - (0.0642 + 2.9808)$. *Ans.* 5.5172.

11. $3 + 4 - 2 \times 4 - 3 \times (8 - 28 + 6)$. *Ans.* 41.

12. $28 \div 4 - 6 - 12 \times (- 8 + 30 - 10)$. *Ans.* $- 143$.

13. $18 - 7 \times 2 + 9 \div 3 - (16 - 51 + 13)$. *Ans.* 15.

14. What is the value of $\dfrac{29.4^2 - \sqrt{25}?}{.008}$ *Ans.* 107420.

Formula

A formula is a rule expressed in a brief and concise way, by the means of certain letters and arithmetical signs. The pupil, therefore, in order to read or solve a formula clearly and easily must be thoroughly acquainted with the arithmetical signs, and the operations which they indicate are to be performed.

The reading and solving of formula may appear to those who have not had the early school advantages very difficult; however, for such, if the following rules which govern the reading and solving of formula generally are given careful study and thought, many of the problems which the mechanic comes across in his daily walks of life, and which have no earthly meaning to him, will be clearly read and easily solved. Formulæ are used for expressing general rules in mathematics and physics.

For instance, the rule of estimating the nominal horse-power for ordinary condensing marine engines is the

square of diameter of cylinder in inches multiplied by the number of cylinders and the product divided by 30. This rule may be expressed by the following formula:

EXAMPLE 1. $\frac{D^2 \times N}{30} =$ *Ans.*

D = Diameter of cylinder in inches.
N = Number of cylinders.

So it is seen by means of two or three letters and signs we can express a long rule. This fully explains the object of all formulæ. Again, the rule for finding the nominal horse-power of paddle steamers is to square the diameter of the piston and multiply by its velocity, and the product divided by 6000 gives the nominal horse-power. Now this rule may be expressed by the formula:

EXAMPLE 2. $\frac{D^2 \times V}{6000} =$ nominal horse-power

Suppose, in the above example, the diameter of the piston is 24 inches, stroke 2 feet, revolution 44 per minute, what would the nominal horse-power be?

Thus $\frac{24^2 \times 176}{6000} = 15.981$ nominal horse-power.

The above examples are given only to demonstrate that a formula which is composed of a few letters and signs will express a long rule, and the student is not supposed to try to solve same until he at least has become familiar with the following examples, which explain the solving of formulæ.

EXAMPLES SHOWING HOW FORMULÆ ARE SOLVED

By referring to the above examples, 1 and 2, it will be seen that in a formula letters represent a value or some

dimension. Thus D^2 in example 1 represents a dimension and N represents a number or quantity. And in example 2 it is seen that D^2 represents 24^2 and V represents a number equal to 176.

The first step to take, then, in solving a formula is to substitute *figures* for *letters*, then proceed as directed by the arithmetical signs of the formula.

The following examples will clearly demonstrate the process of solving all formulæ.

EXAMPLE. If $A = B + C - D + E - F$, what must the value of A be when $B = 12$, $C = 8$, $D = 5$, $E = 9$, and $F = 10$?

We first proceed by substituting the figures for the letters, thus:

$$A = 12 + 8 - 5 + 9 - 10$$

Then proceed as directed by the signs.

$$\begin{aligned} A &= 29 - 15 \\ &= 14 \quad \textit{Ans.} \end{aligned}$$

EXAMPLE. If $X = A + B - C + D - F$, what is the value of X when $A = 20$, $B = 14$, $C = 9$, $D = 8$, and $F = 12$?

First substitute figures for the letters, thus:

$$X = 20 + 14 - 9 + 8 - 12$$

Then proceed as in the arithmetical part.

$$\begin{aligned} X &= 42 - 21 \\ &= 21 \quad \textit{Ans.} \end{aligned}$$

EXAMPLE. If $K = \frac{1}{2} A - \frac{1}{4} D + \frac{1}{5} C - \frac{3}{4} F$, what is the value of K when $A = 12$, $D = 24$, $C = 30$, and $F = 12$?

$$\begin{aligned}
\text{As } A &= 12, \text{ then } \tfrac{1}{2} A = 6 \\
\text{And as } D &= 24, \text{ then } \tfrac{1}{4} D = 6 \\
\text{And as } C &= 30, \text{ then } \tfrac{1}{5} C = 6 \\
\text{And as } F &= 12, \text{ then } \tfrac{3}{4} F = 9 \\
\text{Then } K &= 6 - 6 + 6 - 9 \\
&= 12 - 15 \\
&= -3 \quad \textit{Ans.}
\end{aligned}$$

EXAMPLE. If $K = 3A + 4B + 9C - 7D - E + 3F$, find the value of K when $A = 12, B = 5, C = 2, D = 4, E = 12, F = 1$.

Here $3A = 3$ times $12 = 36$; $4B = 4$ times $5 = 20$; $9C = 9$ times $2 = 18$; $7D = 7$ times $4 = 28$; $E = 12$, and $3F = 3$ times $1 = 3$.

$$\begin{aligned}
\text{Hence } K &= 36 + 20 + 18 - 28 - 12 + 3 \\
&= 77 - 40 \\
&= 37 \quad \textit{Ans.}
\end{aligned}$$

Note when two or more letters are together, without any sign between them, it is always understood that they are to be multiplied together.

$$\text{Thus } \frac{DN}{AB} \text{ is the same as } \frac{D \times N}{A \times B}$$

EXAMPLE. What is the value of N when $N = AB + CD - EF$; when $A = 4, B = 5, C = 3, D = 4, E = 2, F = 10$?

$$\begin{aligned}
N &= 4 \times 5 + 3 \times 4 - 2 \times 10 \\
&= 20 + 12 - 20 \\
&= 32 - 20 \\
&= 12 \quad \textit{Ans.}
\end{aligned}$$

EXAMPLE. If $M = AB - CD + EF - G$, what is the value of M when $A = 2, B = 3, C = 4, D = 5, E = 6, F = 7$, and $G = 20$?

$$\begin{aligned} M &= 2 \times 3 - 4 \times 5 + 6 \times 7 - 20 \\ &= 6 - 20 + 42 - 20 \\ &= 48 - 40 \\ &= 8 \quad \textit{Ans.} \end{aligned}$$

EXAMPLE. If $A = C - \left(\frac{D}{4} - C\right)$, find the value of A when C = 8, D = 20, C = 10.

$$\begin{aligned} A &= 8 - \left(\frac{20}{4} - 10\right) \\ &= 8 - 5 - 10 \\ &= 8 - 15 \\ &= -7 \quad \textit{Ans.} \end{aligned}$$

EXAMPLE. If $N = C - \left(\frac{S}{2} - P\right)$, find the value of N when $C = 8$, $S = 3\frac{1}{2}$, $P = 1\frac{1}{2}$.

$$\begin{aligned} N &= 8 - \left(\frac{3\frac{1}{2}}{2} - 1\tfrac{1}{2}\right) \\ &= 8 - (1\tfrac{3}{4} - 1\tfrac{1}{2}) \\ &= 8 - \tfrac{1}{4} \\ &= 7\tfrac{3}{4} \quad \textit{Ans.} \end{aligned}$$

EXAMPLE. If M = 4 ABC − 3 ED − 5 EFG, what is the value of M when A = 2, B = 3, C = 4, D = 5, E = 6, F = 4, G = 2?

$$\begin{aligned} M &= 4 \times 2 \times 3 \times 4 - 3 \times 4 \times 5 - 5 \times 6 \times 4 \times 2 \\ &= 96 - 60 - 240 \\ &= 96 - 300 \\ &= -204 \quad \textit{Ans.} \end{aligned}$$

NOTE. In the above example there is no sign between the figures and the letters.

The sign × is generally omitted between letters or be-

tween a figure and a letter. Thus AB means the same as A × B and 4 AB the same as 4 × A × B.

EXAMPLE. If $N = \frac{A\,B}{C - D}$, what is the value of N, when A = 6, B = 7, C = 16, D = 10?

$$N = \frac{6 \times 7}{16 - 10} = \frac{42}{6} = 7 \quad \textit{Ans.}$$

EXAMPLE. If $M = A\frac{B\,C}{D - E}$, what is the value of M when A = 2, B = 3, C = 4, D = 16, and E = 8?

$$M = 2\ \frac{3 \times 4}{16 - 8} = \frac{2 \times 3 \times 4}{8} = \frac{24}{8} = 3 \quad \textit{Ans.}$$

EXAMPLE. What is the value of $2 + \frac{A + a - 64}{2000}$ when A = 82 and a = 38?

$$2 + \frac{82 + 38 - 64}{2000} = 2 + \frac{56}{2000} = 2 + .056 = 2.028 \quad \textit{Ans.}$$

EXAMPLE. What is the value of $2\ \frac{A - B + C}{15}$ when A = 20, B = 6, C = 16?

$$2\ \frac{20 - 6 + 16}{15} = 2\ \frac{30}{15} = 2 \times \frac{30}{15} = \frac{60}{15} = 4 \quad \textit{Ans.}$$

EXAMPLE. $6\ \frac{D^3 - d^3}{A}$ What is the value of this when D = 14, d = 12, and A = 15?

$$6\ \frac{14^3 - 12^3}{15} = 6\ \frac{2744 - 1728}{15}\ 6 \times \frac{1016}{15} = \frac{6096}{15}$$

$$= 406.4 \quad \textit{Ans.}$$

EXAMPLE. $A = \frac{(B - C)\ (T - K)}{M - R} \times .003\ N.$

What is the value of the above when B = 120, C = 32, T = 67, K = 32, and N = 3375, M = 120, R = 67?

$$\text{Thus } A = \frac{(120 - 32)\ (67 - 32)}{120 - 67} \times .003 \times 3375.$$

$$= \frac{(88 \times 35)}{53} \times .003 \times 3375.$$

$$= \frac{3080}{53} \times .003 \times 3375 = \frac{31185.000}{53} = 588.396 \quad \textit{Ans.}$$

Note in the above example there is no sign between the brackets. Whenever this is the case (that is, whenever there is no sign between two quantities) the two quantities must be multiplied together.

Example. What is the value of $\frac{S^2}{8C}$ when $S = 32$ and $C = 32 \times 2$?

$$\text{Thus } \frac{S^2}{8C} = \frac{32 \times 32}{8 \times 32 \times 2} = \frac{1024}{512} = 2. \quad \textit{Ans.}$$

PART III

MENSURATION

TABLE OF DECIMAL EQUIVALENTS

1/8 = .125	1/64 = .01563	11/32 = .34375	21/32 = .65625
	1/32 = .03125	23/64 = .39538	43/64 = .67188
	3/64 = .04688	3/8 = .375	11/16 = .6875
	1/16 = .0625	25/64 = .39063	45/64 = .70313
1/4 = .25	5/64 = .07813	13/32 = .40625	23/32 = .71875
	3/32 = .09375	27/67 = .42188	47/64 = .73438
	7/64 = .10938	7/16 = .4375	3/4 = .75
3/8 = .375	1/3 = .125	29/64 = .45313	49/64 = .76563
	9/64 = .14063	15/32 = .46875	25/32 = .78125
	5/32 = .15625	31/64 = .48438	51/64 = .79688
1/2 = .5	11/64 = .17188	1/2 = .5	13/16 = .8125
	3/16 = .1875	33/64 = .51563	53/64 = .82813
	13/64 = .20313	17/32 = .53125	27/32 = .84375
5/8 = .625	7/32 = .21875	35/64 = .54688	55/64 = .85938
	15/64 = .23438	9/16 = .5625	7/8 = .875
3/4 = .75	1/4 = .25	37/64 = .57813	57/64 = .89063
	17/64 = .26563	19/32 = .59375	29/32 = .90625
	9/32 = .28125	39/64 = .60938	59/64 = .92188
	19/64 = .29688	5/8 = .625	15/16 = .9375
7/8 = .875	5/16 = .3125	41/64 = .64063	61/64 = .95313
	21/64 = .3283		31/32 = .96875
			63/64 = .98438
			1 = 1.00000

EXPLANATION OF TERMS

The Point

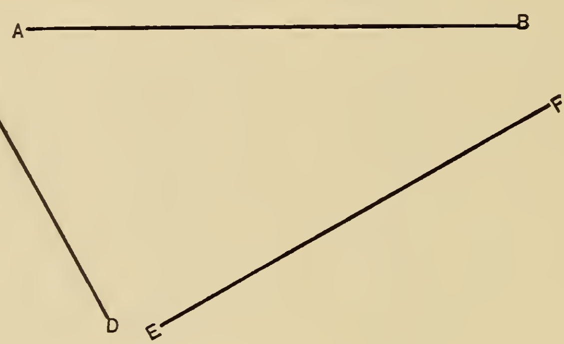
A point is that which has position but no dimension. An object having a position but no extension. A place having a specific position but no size. That is, a point has neither length, breadth, nor thickness, hence it has no dimension.

The Line

The Straight or Right Line

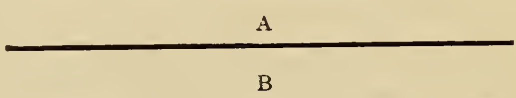
Straight means erect, tight, without bend, like a string, for instance, which is tightly stretched. A line is length without breadth. That is, a line is space of one dimension (length). And a line which lies evenly between two extreme points is called a straight or right line. No matter what the position of the points so long as they are connected by a line without bend, that line is straight.

Thus, the lines A B, C D, E F are all straight lines.



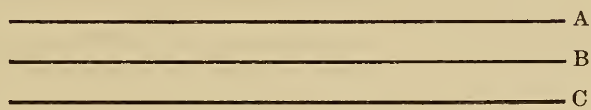
Parrallel Lines

Parallel means alike, similar to, having the same direction or course. Hence parallel lines are lines which are alike, lines having the same direction or course and lying in the same plane as the lines A, B.



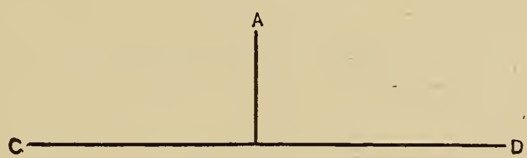
Now if we draw another line, C, having the same

direction and course as the lines A, B, it will be parallel to them, thus the three lines A, B, C, are all parallel lines.



The Vertical and Perpendicular Line

A vertical and perpendicular line are one and the same thing. The word vertical relates to the word *vertea,* which means the highest point or summit. A vertical line may be thought of as such a line as would be formed by a string or line which is suspended from some point overhead; such a line would be upright and would be perpendicular to the horizon. Thus the line A is vertical and is perpendicular to the line C D.



The Diagonal and Oblique Line

Diagonal and oblique have practically the same meaning. Diagonal means across from angle to angle, oblique means aslant, or slanting. By diagonal line, then, is meant a slanting line.

Thus

The Horizontal Line

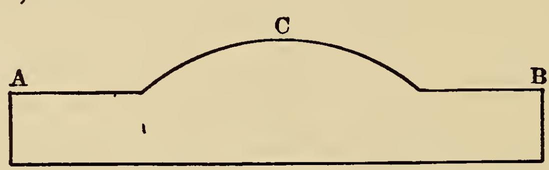
By horizontal line is meant a line that is parallel to the horizon; such a line is neither vertical or inclined and is represented thus: Horizontal.

The Curved Line

A curved line is a line whose direction changes continually along its path thus 
or 

The Convex Line

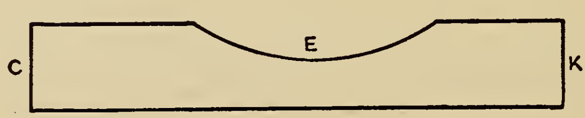
A convex line is a curved, rounded, or arched line, which curves away from the line of view. Thus the curved part, C, of the figure A, C, B, is said to be convex, because it curves away from the ends, A and B, of the figure A, C, B.



A sphere, or circle, looked at from any point without, presents a convex surface or line.

The Concave Line

The concave line is the reverse of the convex line. Concave means incurved. Thus the curved part, E, of the figure C, E, K, is said to be concave because it curves in.



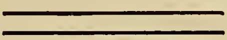
A sphere, or circle, when looked at from any point within, presents a concave surface or line.

Examples for Exercise

What is the name of this  line?

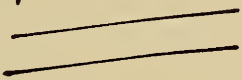
Ans. Horizontal line.

What is the name of that line which lies evenly between two points? *Ans.* Straight line.

What are these lines called? 

Ans. Parallel lines.

What is the name of these lines?  *Ans.* Vertical or perpendicular.

What is the name of these lines?  *Ans.* Diagonal or oblique.

What is the name of this line?  *Ans.* Curved line.

What is the difference between a convex and concave line? *Ans.* The convex is outcurved and the concave is incurved.

MENSURATION

Mensuration is the art of measuring length and volume, content, etc. For instance, the art of determining the length of a circle or the contents of a cylinder or other shaped vessels, and it is necessary that the pupil should become thoroughly familiar with the names of the different shaped surfaces given in this chapter, and at any time be able to form a mental conception of same, because mensuration treats of the measurement of such curved lines, surfaces, and solids.

The Circle

The circle is a plane figure formed by a curved line called the "circumference," (Fig. 1), and is such that all right lines drawn from a certain point within, called the "center," to the circumference, are equal to each other.

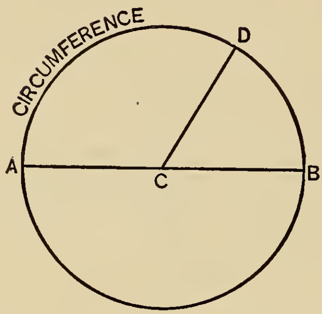


Fig. 1

A radius of a circle is any right line drawn from the center to the circumference, such as C D or C A or C B.

A diameter of a circle is a straight line drawn through the center and ending both ways at the circumference, as A B.

To Find the Circumference of a Circle

Rule. Multiply 3.1416 by the diameter.

Example. What is the circumference of a circle whose diameter is 4 inches.

Process:

$$\begin{array}{r} 3.1416 \\ 4 \\ \hline 12.5664 \end{array}$$

12.5664 inches. *Ans.*

Example. What is the circumference of a circle whose diameter is $3\frac{1}{2}$ inches?

Process:

$$\begin{array}{r} 3.1416 \\ 3.5 \\ \hline 157080 \\ 94248 \\ \hline 10.99560 \end{array} \qquad 3\tfrac{1}{2} = 3.5$$

10.99560 inches. *Ans.* (Almost 11 inches

Examples for Exercise

1. What is the circumference of a circle whose diameter is 4 inches? *Ans.* 12.5664.

2. What is the circumference of a circle whose diameter is 4.75? *Ans.* 14.922600.

3. What is the circumference of a circle whose diameter is $4\frac{3}{4}$? *Ans.* 14.922600.

4. What is the circumference of a circle whose diameter is 5.5? *Ans.* 17.27880.

5. What is the circumference of a circle whose diameter is 6.6? *Ans.* 20.73456.

6. What is the circumference of a circle whose diameter is 5.6? *Ans.* 17.59296.

To Find the Area of a Circle

By area is meant that which is confined within some specific surface space. For instance, the base, or site, on which a building stands.

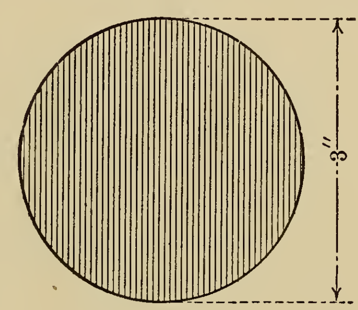


Fig. 2

Thus, in the following example, which is to find the area of a circle whose diameter is 3 inches, the answer tells the number of square inches contained within a circle whose diameter is 3 inches, or the number of square inches that would be enclosed on a plane surface by a circle whose diameter is 3 inches.

Example. Find the area of a circle whose diameter is 3 inches. (Fig. 2.)

Rule. Multiply .7854 by the square of the diameter. Thus:

3
3
9 square of diameter

.7854
9
7.0686 square inches. *Ans.*

EXAMPLE. The diameter of a circle is 3.5, what is its area?

3.5
3.5
175
105
12.25

.7854
12.25
39270
15708
15708
7854
9.621150 square inches. *Ans.*

EXAMPLES FOR EXERCISE

1. What is the area of a circle whose diameter is 5.5 inches? *Ans.* 23.758350.
2. What is the area of a circle whose diameter is 4 inches? *Ans.* 12.5664.
3. What is the area of a circle whose diameter is 3.75 inches? *Ans.* 11.04468750.
4. What is the area of a circle whose diameter is 2 inches? *Ans.* 3.1416.
5. What is the area of a circle whose diameter is $6\frac{7}{8}$ inches? *Ans.* 37.0910058750.
6. What is the area of a circle whose diameter is 4.6 inches? *Ans.* 16.619064.

THE ELLIPSE

An ellipse may be called a flattened circle, the longest diameter of which is called the "transverse axis" (*latus transversum*) and the shortest is called the "conguatt axis." (Fig. 3.)

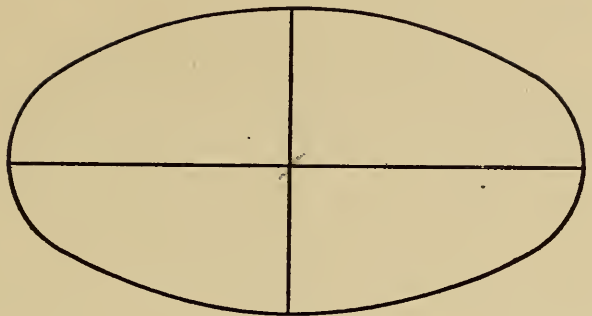


FIG. 3

TO FIND THE CIRCUMFERENCE OF AN ELLIPSE

RULE. Multiply 3.1416 by half the sum of the two diameters.

EXAMPLE. What is the circumference of an ellipse whose diameters are 6 and 4 inches?

$$\begin{array}{r} 6 \\ \underline{4} \\ 2\overline{)10} \\ 5 \end{array} \times 3.1416 = 15.7080 \text{ inches. } \textit{Ans.}$$

EXAMPLE. What is the circumference of an ellipse whose diameters are $3\frac{3}{4}$ and $7\frac{1}{2}$?

$$\begin{array}{rr} 3\frac{3}{4} = & 3.75 \\ 7\frac{1}{2} = & \underline{7.5} \\ & 2\overline{)11.25} \\ & 5.625 \end{array} \qquad \begin{array}{r} 3.1416 \\ \underline{5.625} \\ 157080 \\ 62832 \\ 188496 \\ \underline{157080} \\ 17.6715000 \end{array} \text{ inches. } \textit{Ans.}$$

TO FIND THE AREA OF AN ELLIPSE

RULE. Multiply .7854 by the product of the two diameters.

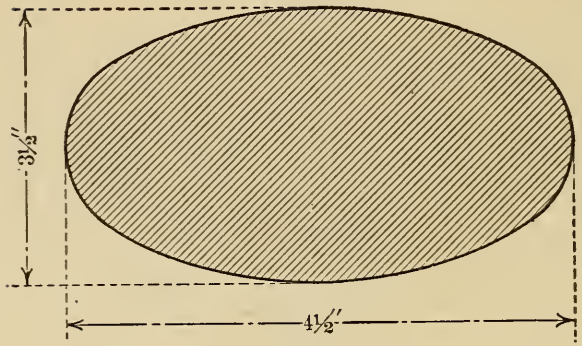


Fig. 4

Example. What is the area of an ellipse whose diameters are $3\frac{1}{2}$ and $4\frac{1}{2}$ inches? (Fig. 4.)

$$\begin{array}{rrr} 3\frac{1}{2} = & 3.5 & \\ 4\frac{1}{2} = & \underline{4.5} & \\ & 175 & \\ & \underline{140} & \\ \text{Product} & 15.75 & \end{array} \qquad \begin{array}{r} .7854 \\ \underline{15.75} \\ 39270 \\ 54978 \\ 39270 \\ \underline{7854} \\ 12.370050 \end{array}$$

12.370050 square inches. *Ans.*

What is the area of an ellipse whose diameters are 5 and 10 inches?

$$\begin{array}{r} 5 \\ \underline{10} \\ 50 \end{array} \qquad \begin{array}{r} .7854 \\ \underline{50} \\ 39.2700 \end{array}$$

39.2700 square inches. *Ans.*

Examples for Exercise

1. What is the area of an ellipse whose diameters are $5\frac{3}{4}$ inches and $4\frac{1}{4}$ inches? *Ans.* 19.19321250.

2. What is the area of an ellipse whose diameters are 7 feet and 9 feet? *Ans.* 49.4802 square feet.

3. What is the area of an ellipse whose diameters are 3.5 feet and 7.5 feet? *Ans.* 20.616750.

4. What is the area of an ellipse whose diameters are 3.5 feet and 4.5 feet? *Ans.* 12.370050.

5. What is the area of an ellipse whose diameters are 5 inches and 10 inches? *Ans.* 39.2700 square inches.

The Triangle

A triangle is a figure formed by three right lines joined together end to end. The three lines are called its "sides." Thus *a*, *b*, *c*, are the sides of the triangle 1. (Fig. 5.)

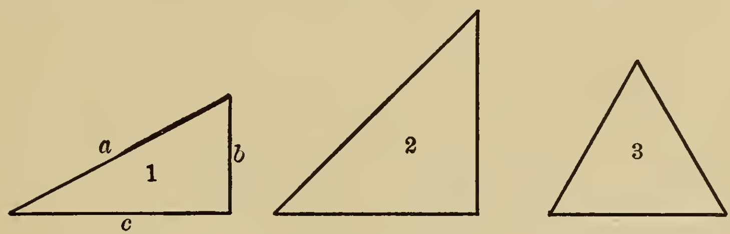


Fig. 5

Any three-cornered or three-sided figure body bounding a three-sided space is called a triangle.

A triangle whose three sides are unequal is called a Scalene. (Triangle 1.)

A triangle having two of its sides equal is called an "Isosceles Triangle." (Triangle 2.)

And a triangle all of whose sides are equal is called an "Equilateral Triangle." (Triangle 3.)

To Find the Area of a Triangle

Rule. Multiply the base by half the perpendicular height.

Example. What is the area of a triangle whose base is 4 feet and whose height is 4 feet?

Half the height = 2 feet; thus 2 × 4 = 8 square feet.

Example. Find the area of a triangle whose base is 12 inches and whose height is 8 inches. (Fig. 6.)

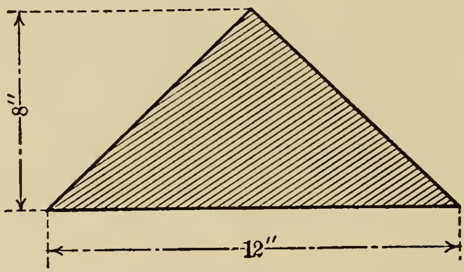


Fig. 6

Half height = 4 inches; then 4 × 12 = 48 square inches

Example. Find the area of a triangle whose base is 12 inches and whose height is 4 inches. (Fig. 7.)

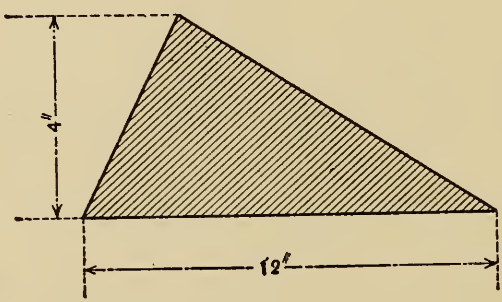


Fig. 7

Half the height = 2 inches; then 2 × 12 = 24 square inches.

Example. Find the area of a triangle whose base is 15 feet and whose height is 9 feet. (Fig. 8.)

Half the height = 4.5; then 4.5 × 15 feet.

$$\begin{array}{r} 15 \\ 4.5 \\ \hline 75 \\ 60 \\ \hline 67.5 \end{array}\text{ square feet.}$$

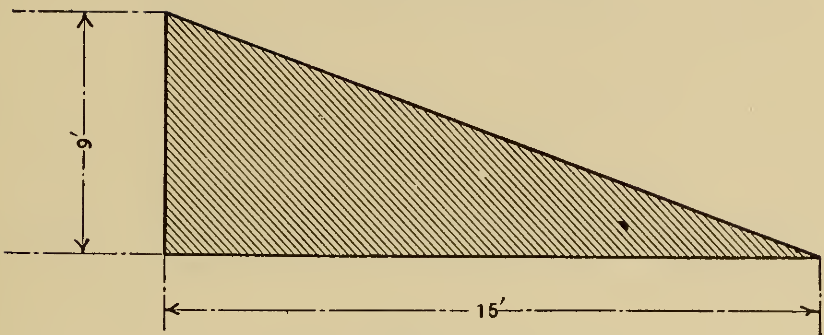


FIG. 8

EXAMPLES FOR EXERCISE

Find the area of triangles having the dimensions below.

1. Base 15 feet, height 4.5. *Ans.* 33.75 square feet.
2. Base 14.75 feet, height $6\frac{1}{4}$ feet. *Ans.* 46.09375 square feet.
3. Base 8 inches, height 4 inches. *Ans.* 16 inches.
4. Base 27.5 feet, height 5 feet. *Ans.* 68.75 square feet.

THE SQUARE

A square is an area bounded by four equal sides. (Fig. 9.) A figure all of whose sides are equal and all of whose angles are right angles.

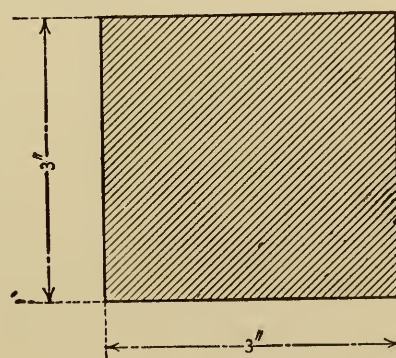


FIG. 9

To Find the Area of a Square

Rule. Multiply the base by the height, or the length by the breadth.

Example. What is the area of a square whose base is 3 inches? (Fig. 9.)

$$\begin{array}{l} 3 \\ \underline{3} \\ 9 \text{ square inches.} \quad \textit{Ans.} \end{array}$$

Example. What is the area of a square whose base is 3.5 feet?

$$\begin{array}{r} 3.5 \\ \underline{3.5} \\ 175 \\ \underline{105} \\ 12.25 \end{array} \text{ square feet.}$$

Examples for Exercise

Find the area of the following squares:

1. Of a square whose base is 9 feet. *Ans.* 81 square feet.
2. Of a square whose base is 36 inches. *Ans.* 9 square feet.
3. Of a square whose base is 3 feet. *Ans.* 9 square feet.
4. What is the area of a square whose side is 2.5 feet? *Ans.* 6.25 square feet.

The Oblong

An oblong is a figure whose sides are perpendicular to its base and whose length is greater than its breadth. (Fig. 10.)

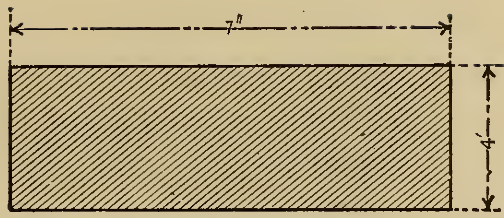


FIG. 10

TO FIND THE AREA OF AN OBLONG

RULE. Multiply the length by the breadth.

EXAMPLE. What is the area of an oblong whose length is 7 feet and whose height is 4 feet? (Fig. 10.)

$$\begin{array}{l} 7 = \text{base} \\ \underline{\ 4} = \text{height} \\ 28 \text{ square feet.} \quad \textit{Ans.} \end{array}$$

EXAMPLE. What is the area of an oblong whose base is 12 feet and height 4 feet?

$$\begin{array}{l} 12 \\ \underline{\ \ 4} \\ 48 \text{ square feet.} \quad \textit{Ans.} \end{array}$$

EXAMPLES FOR EXERCISE

Find the area of the following oblongs:

1. Base 12 feet, height 6 feet. *Ans.* 72 square feet.
2. Base 5.5 feet, height 3.5 feet. *Ans.* 19.25 square feet.
3. Base $9\frac{3}{4}$ inches, height 5 inches. *Ans.* 48.75 square inches.
4. Base 15 feet, height 2.5 feet. *Ans.* 37.5 square feet.

The Rhomboid

A rhomboid is a four-sided figure whose opposite sides are parallel, whose dimensions are greater one way than another, but whose ends are *not* perpendicular to its base.

To Find the Area of a Rhomboid

Rule. Multiply the base by the perpendicular height.

Example. Find the area of a rhomboid whose base is 9 feet and perpendicular height 3 feet. (Fig. 11.)

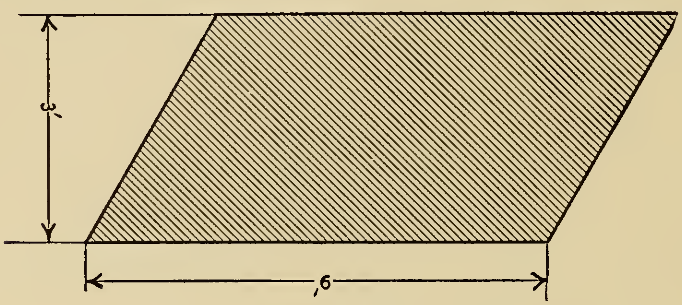


Fig. 11

$$\begin{array}{r} 9 \\ \underline{3} \\ 27 \end{array} \text{ square feet. } \textit{Ans.}$$

Example. Find the area of a rhomboid whose base is 6 feet and whose height is $3\frac{1}{2}$ feet.

$$\begin{array}{r} 6. \\ \underline{3.5} \\ 30 \\ \underline{18} \\ 21.0 \end{array} \text{ square feet.}$$

What is the area of a rhomboid whose base is 3 feet and whose perpendicular height is 4 feet? (Fig. 12.)

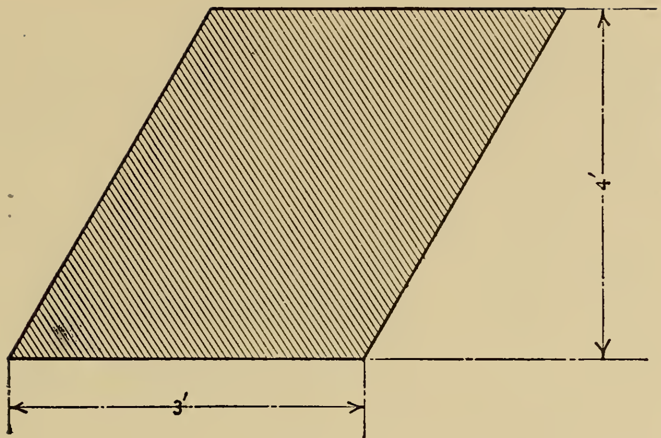


FIG. 12

$$\begin{array}{r} 3 \\ \underline{4} \\ 12 \end{array}$$ square feet. *Ans.*

EXAMPLE. Find the area of a rhomboid whose base is 2 feet and whose height is $5\frac{1}{2}$ feet. (Fig. 13.)

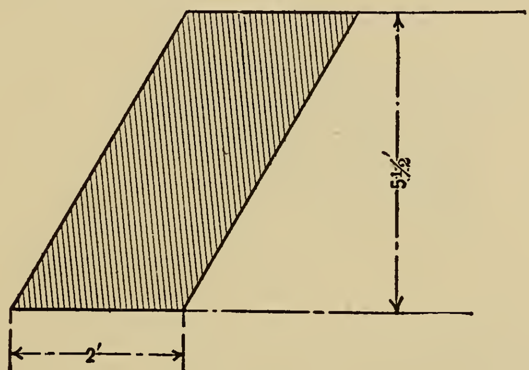


FIG. 13

$$\begin{array}{r} 2. \\ \underline{5.5} \\ 10 \\ \underline{10} \\ 11.0 \end{array}$$ square feet. *Ans.*

The Trapezoid

A trapezoid is a plain four-sided figure, having two of its opposite sides parallel and the other two not so. (Figs. 14 and 15.)

Fig. 14

Fig. 15

To Find the Area of a Trapezoid

Rule. Multiply half the sum of the two parallel sides by the distance between them.

Example. What is the area of the following trapezoid? (Fig. 16.)

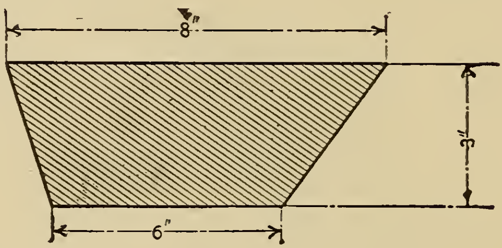


Fig. 16

Here, the lines 8″ and 6″ being the parallel sides, we multiply half their sum by the perpendicular distance between them, which is 3 inches. Thus:

$$\begin{array}{r l} 8 & \\ \underline{6} & \\ 2\overline{)14} & \\ 7 & \times 3 = 21 \text{ square inches.} \end{array}$$

EXAMPLE. What is the area of a trapezoid whose parallel sides are 5.5 feet and 9.75 feet, and the distance between them is 2 feet? (Fig. 17.)

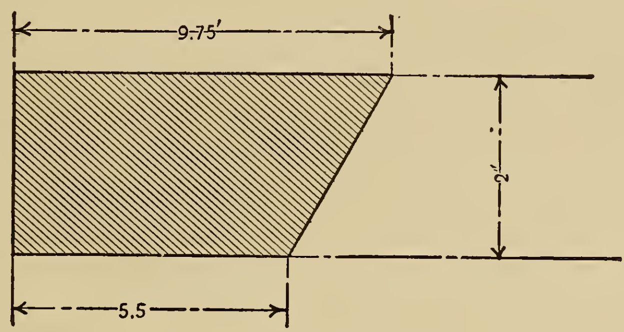


FIG. 17

Thus:

$$\begin{array}{r} 9.75 \\ 5.5 \\ \hline 2)\overline{15.25} \\ \hline 7.625 \times 2 = 15.250 \text{ square feet} \end{array}$$

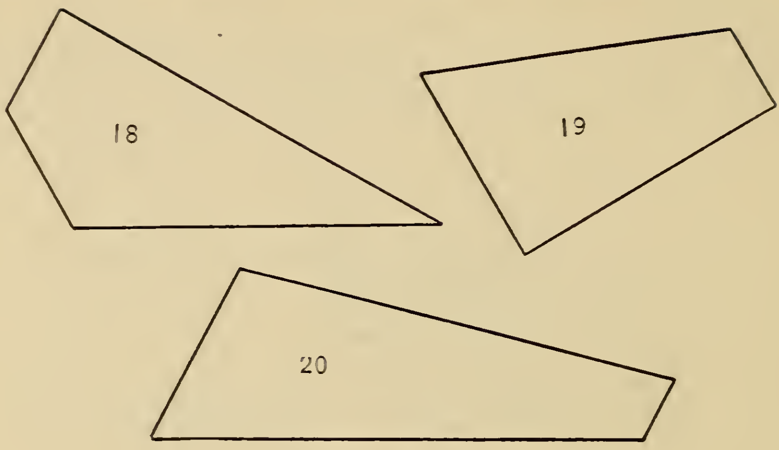
EXAMPLES FOR EXERCISE

1. What is the area of a trapezoid, the longer of the two parallel sides being 130 feet, the shorter 100 feet, and the height 80 feet? *Ans.* 9200 square feet.

2. What is the area of a trapezoid, the longer of the two parallel sides being 25 feet, and the shorter 23 feet, and the width being $1\frac{1}{4}$ feet? *Ans.* 30 square feet.

THE TRAPEZIUM

A trapezium is any plane figure contained by four straight lines, no two of which are similar. (Figs. 18, 19, 20.)



Figs. 18, 19, 20

To Find the Area of a Trapezium

Rule. Divide the trapezium into two triangles, by connecting its opposite angles, making this line of division the base line of both triangles. Measure the perpendicular height of each triangle from this base line. Then find the area of each triangle, add both together, and the sum is the area of the whole figure.

Example. Find the area of the following trapezium. (Fig. 21.)

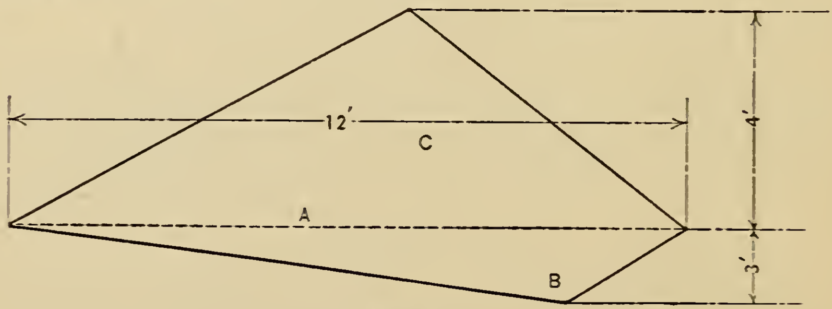


Fig. 21

Thus $2\overline{)4}$

$$2 \times 12 = 24 \text{ sq. ft., area of triangle C}$$

$2\overline{)3}$

$$1.5 \times 12 = 18.0 \text{ sq. ft., area of triangle B}$$

$$\overline{42.0} \text{ sq. ft.} \quad \textit{Ans.}$$

Here we first of all divide the figure in two by the dotted line (A); we then have two triangles, B and C, and this line (A) proves the base for both. We then find the area of each triangle separately, add them both together, and the sum 42.0 equals the area of the whole figure.

EXAMPLE. What is the area of the following trapezium? (Fig. 22.)

Thus $2\overline{)8}$

$$4 \times 20 = 80$$

$2\overline{)4}$

$$2 \times 20 = 40$$

$$\overline{120} \text{ sq. ft.} \quad \textit{Ans.}$$

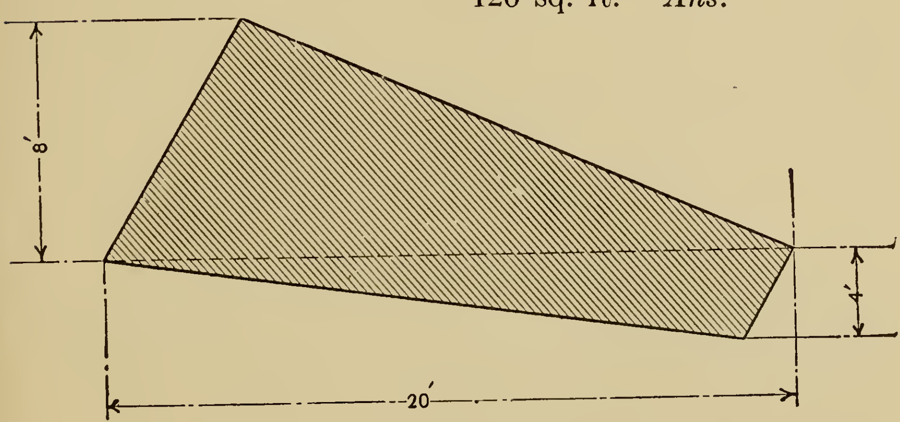


FIG. 22

TO FIND THE SURFACE OF A CYLINDER

RULE. Multiply the diameter by 3.1416 and multiply the product by the height.

Example. Find the number of square inches in surface of a cylinder of the following dimensions. (Fig. 23.)

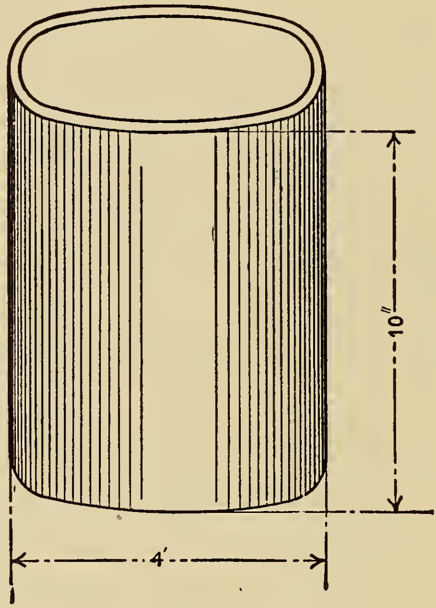


Fig. 23

Thus $4'' =$ diameter
And $10'' =$ height
Then $4'' \times 3.1416 = 12.5664$ circumference

$$\begin{array}{r} 12.5664 \\ 10 \\ \hline 125.6640 \end{array}$$

125.6640 sq. in. *Ans.*

Example. What is the surface of a cylinder whose diameter is 9 inches and height 15 inches?

$9 \times 3.1416 = 28.2744 =$ circumference

Thus, $28.2744 \times 15 = 424.1160$, area of surface in square inches.

The Sphere

A sphere is a body bounded by a curved surface, all parts of which are an equal distance from a certain point within, called the "center." The diameter of a sphere is a straight line drawn through its center, terminating both ways in the surface.

The circumference of a sphere is the greatest distance around the sphere. (Fig. 24.)

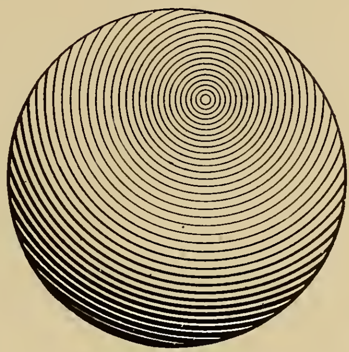


Fig. 24

To Find the Surface of a Sphere

Rule. Multiply 3.1416 by the square of the diameter.

Example. What is the surface of a sphere whose diameter is 6 feet?

$$\begin{array}{r} \text{Thus}\quad 6 \\ \underline{6} \\ 36 \end{array} = \text{sq. of diameter} \times 3.1416 = \text{Answer.}$$

$$\begin{array}{r} 3.1416 \\ \underline{36} \\ 188496 \\ \underline{94248} \\ 113.0976 \end{array}$$ area of surface in square feet. *Ans.*

Example. What number of square inches of gold leaf will cover a sphere whose diameter is 18 inches?

$$\begin{array}{r} 18 \\ \underline{18} \\ 144 \\ \underline{18} \\ 324 \end{array}$$ square of diameter

$$\begin{array}{r} 3.1416 \\ \underline{.324} \\ 125664 \\ 62832 \\ \underline{94248} \\ 1017.8784 \end{array}$$ sq. in. *Ans.*

The contents of a sphere are equal to the product of $\frac{1}{6}$ of 3.1416 multiplied by cube of diameter.

EXAMPLE. How many cubic feet of gas will fill a spherical balloon whose diameter is 6 feet?

$$\tfrac{1}{6} \text{ of } 3.1416 \times 6^3 = 113.097 \text{ cubic feet.} \quad \textit{Ans.}$$

VOLUME MEASURE AND CONTENTS OF SOLIDS

RECTANGULAR SOLIDS

TO FIND THE CONTENTS OF A RECTANGULAR SOLID

A rectangular solid is a figure bounded by six rectangles. (Fig. 25.)

The dimensions of a rectangular figure are its length, breadth, and thickness, and the contents or volume of a rectangular figure is the space contained within its bounding surfaces.

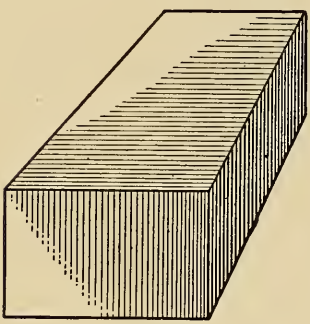


FIG. 25

The volume or content of any rectangular is determined by the following rule:

RULE. Multiply the length, breadth, and height together.

EXAMPLE. What is the content of a rectangular solid whose length is 3 feet, breadth 2 feet, height 2 feet?

$$\begin{array}{r} 3 \\ \underline{2} \\ 6 \\ \underline{2} \\ 12 \end{array} \text{ cubic feet.} \quad \textit{Ans.}$$

EXAMPLE. How many cubic feet in a rectangular figure, each of whose sides measures 3 feet?

$$\begin{array}{r} 3 \\ \underline{3} \\ 9 \\ \underline{3} \\ 27 \end{array} \text{ cubic feet.} \quad \textit{Ans.}$$

EXAMPLE. How many cubic feet of water will a vessel hold whose inside dimensions are, length 5 feet, breadth 4 feet, and depth 3 feet?

$$5 \times 4 \times 3 = 60 \text{ cubic feet of water}$$

THE CYLINDER

A cylinder is a round body of a uniform diameter, whose bases are equal and parallel circles. (Fig. 26.)

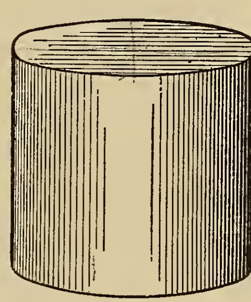


FIG. 26

TO FIND THE CUBIC CONTENTS OF A SOLID CYLINDER

RULE. Find the area of the base and multiply this by the height or length.

EXAMPLE. What are the cubic contents of a cylinder whose diameter is 2 feet and whose height or length is 7 feet?

Thus 2

$$\begin{array}{l} 2 \\ \underline{2} \\ 4 \times .7854 \text{ is} \end{array} \quad \begin{array}{r} .7854 \\ \underline{4} \\ 3.1416 = \text{area of base in sq. ft.} \\ \underline{7} = \text{height of cylinder} \\ 21.9912 \text{ cubic feet.} \quad \textit{Ans.} \end{array}$$

EXAMPLE. How many cubic feet of water will a cylindrical shaped vessel hold, whose inside dimensions are, diameter 4 feet, and height $7\frac{1}{2}$ feet?

4	.7854
4	16
16	47124
	7854
	12.5664 = number of sq. ft. in area of base
	7.5 = height
	628320
	879648
	94.24800 cubic feet. *Ans.*

THE PYRAMID

A pyramid is a body whose base is a polygon but whose sides are all triangles, meeting at one point (A), called the vertex of the pyramid. (Fig. 27.)

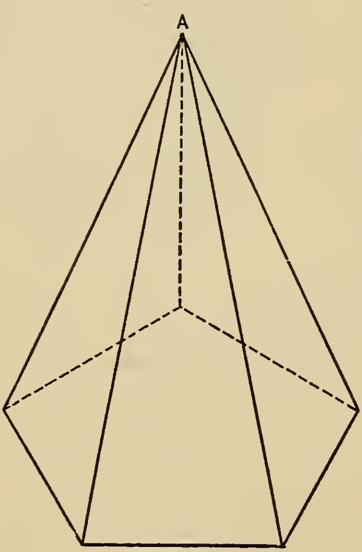


FIG. 27

Polygon means many curves or many angles.

A polygon, then, is a plane figure bounded by three, four, five, six, or any number of sides.

Accordingly, the base of a pyramid may be triangular, square, pentagonal, etc., and pyramids are named for the figure or shape of their base.

A pyramid having a three-curved or triangular base is called a trianglor pyramid, and one having a square base is called a square pyramid,

and one having a five-sided or pentagonal base is called a pentagonal pyramid.

To Find the Cubic Contents of a Pyramid

Rule. Multiply the area of the base by one third of its perpendicular height (altitude).

Example. How many cubic inches are there in a pyramid of the following dimensions: base 3 inches square, and height (altitude), 12 inches?

$$\begin{array}{r l}
3 & \\
3 & \\
\hline
9 & = \text{square inches area of base} \\
3\overline{)12} & \\
\hline
4 & = \text{one third of altitude} \\
9 & \\
4 & \\
\hline
36 & \text{cubic inches.} \quad \textit{Ans.}
\end{array}$$

Example. How many cubic inches are there in a pyramid whose base is a triangle, each of whose sides measures 3 inches and whose height is 15 inches? Thus:

$$\begin{array}{r l}
3 & \\
1.5 & = \text{one half of perpendicular height} \\
\hline
4.5 & = \text{area of triangle base} \\
5 & = \text{one third of height of pyramid} \\
\hline
22.5 & = \text{number of cubic inches.} \quad \textit{Ans.}
\end{array}$$

Process. We first find the area of the triangular base, according to the rule given for finding the area of a triangle, which we multiply by one third of the perpendicular height of the pyramid, the product 22.5 thus obtained being the answer.

The Cone

A cone is a body whose base is a circle and whose convex surface tapers uniformly to a point, "A," called the vertex of the cone. (Fig. 28.)

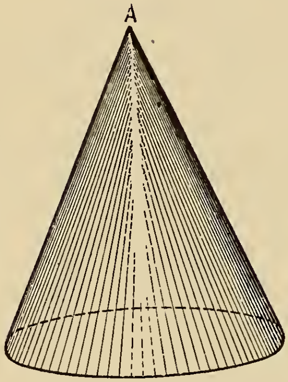


Fig. 28

To Find the Cubic Contents of a Cone

Rule. Multiply the area of the base by one third the perpendicular height.

Example. Find the cubic inches in a cone whose base is 3 inches diameter and whose height is 15 inches.

3	.7854	
3	9	
9	7.0686	= area in square inches of base.
	5	= one third of perpendicular height of cone.
	35.3430	= cubic inches contained in cone.

Example. How many cubic inches of water will a cone-shaped vessel hold, the diameter of whose base is $3\frac{1}{2}$ inches and whose height is 12 inches?

3.5	.7854	
3.5	12.25	
175	39270	
105	15708	
12.25	15708	
	7854	
	9.621150	= area of base.
	4	= one third of perpendicular height.
	38.484600	cubic inches of water. *Ans.*

The Frustum

A frustum is that part of any solid figure which is between two planes, either parallel or inclined to each other. It is the part of a solid which remains after cutting off the top part by a plane parallel to the base.

The "frustum" actually means, a piece; particularly, a remaining piece of something of which a part is lacking.

A frustum of a cone, or pyramid, then, is the part which remains after cutting off the top by a plane parallel to the base. (Figs. 29 and 30.)

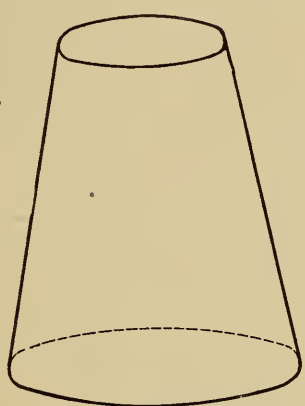


Fig. 29

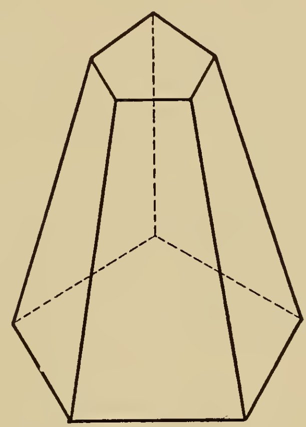


Fig. 30

To Find the Cubic Contents of a Frustum of a Cone

Rule. Find the sum of the squares of the two diameters, add on to this the product of the two diameters, then multiply by .7854 and then multiply by one third the height.

Example. Find the cubic contents of a frustum of a cone whose large diameter is 12 inches, small diameter 6 inches, and height 4 inches.

```
   12                                        6
   12                                        6
  ---                                       --
  144 = square of large diameter            36 = sq. of small
   36                                               [diameter.
  ---
  180 = sum of squares of both diameters
   72 = product of both diameters
  ---
  252
    .7854                  12
  -------                   6
    1008                   --
   1260                    72 = product of both diameters.
  2016
 1764                      3)4
 ---------                 ----
 197.9208                   1.33 = one-third of thickness.
     1.33
 ---------
 5937624
5937624
1979208
----------
263.234664 cubic inches.   Ans.
```

EXAMPLE. How many cubic inches in the body shown in Figure 31?

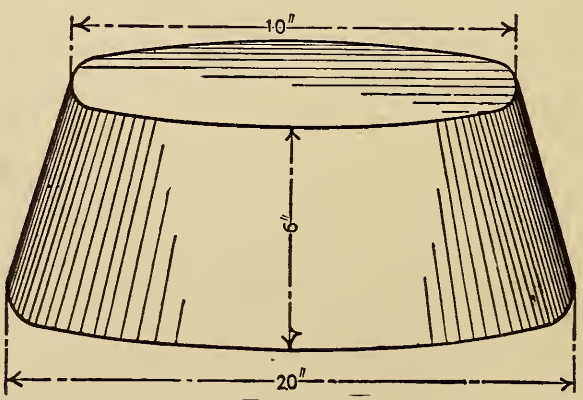


FIG. 31

```
        20
        20
      ----
       400 = square of large diameter.
       100
      ----
       500 = sum of square of both diameters.
       200 = product of both diameters.
      ----
       700
     .7854
    ------
      2800
     3500
    5600
   4900
  --------
  549.7800
         2 = one-third of thickness.
 ---------
1099.5600 cubic inches.   Ans.

        10
        10
      ----
       100 = sq. of small diameter.
        20
        10
      ----
       200 = product of both diameters.
      3) 6
      ----
         2 = one-third of thickness.
```

To Find the Cubic Contents of a Frustum of a Pyramid

Rule. The sum of the areas of the two bases added to the square root of their product, multiplied by one third of the altitude.

Example. What are the contents of the frustum of a square pyramid whose height is 30 feet, and whose side at the base is 20 feet and at the top ten feet? (Fig. 32.)

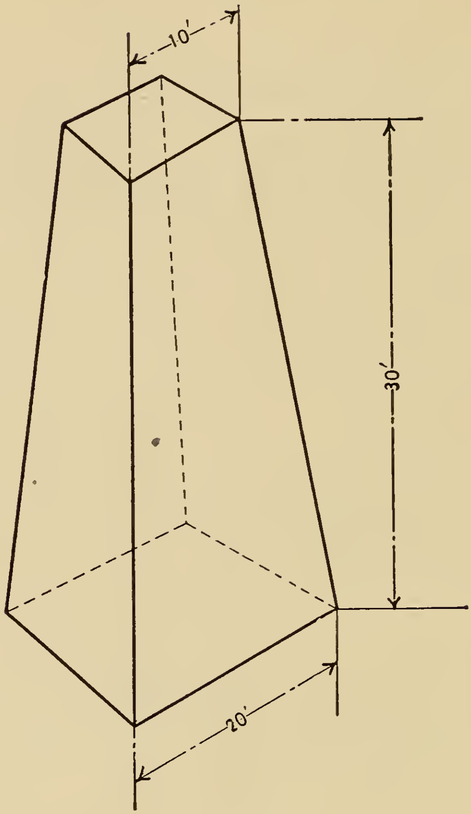


Fig. 32

Process:

$20 \times 20 = 400$; $10 \times 10 = 100$; $400 \times 100 = 40000$;
$\sqrt{40000} = 200$; $200 + 400 + 100 = 700$;
$30 \div 3 = 10$; $700 \times 10 = 7000$ cubic feet.

PART IV

WEIGHT, SPECIFIC GRAVITY, HOW THE DIMENSIONS, MEASUREMENTS AND WEIGHT OF DIFFERENT SHAPED VESSELS ARE FOUND, AND HOW THE WEIGHT OF DIFFERENT PARTS IS FOUND

WEIGHT

By weight, is meant the heaviness of a body, the downward force a body has; which force is created by the action of a force called the "force of gravity," working upon all its particles.

The "force of gravity" is that attraction which the earth exerts upon all bodies near it, tending to draw them toward its center. When this force is resisted it gives rise to pressure, which is called weight. Weight, therefore, is due to and is the effect of resisted gravity.

SPECIFIC GRAVITY

In nature all substances have, under the same conditions, a weight "specific or peculiar" to themselves. This is due to the fact that like volumes of different materials contain variable amounts of matter.

There is, for instance, more matter contained in a cubic inch of lead than in a like volume of wood, and the greater the density of the body or, in other words, the greater the amount of matter contained within any specific space, the greater the weight, for the reason that the action of gravity on all bodies is proportional to their volume or density.

Therefore, under the same conditions, a cubic inch of lead will weigh more than a cubic inch of wood, and the comparative weights of equal volumes of different substances are called their "specific" gravities; and the standard of reference is pure water at a temperature of 60° Fahrenheit.

In other words, the "specific gravity" of a body is its

relative weight, that is, the number of times it is "heavier" or "lighter" than a body of the same size of a different substance, and in order to determine the relative weights of equal sized bodies of different composition a standard is taken, which is pure water at the temperature of 60° Fahrenheit.

There are different methods used for taking the specific gravities of bodies, one of which, called the "Hydrostatic Balance," is here described. By this method a regular balance is used, having two scale pans. The body whose specific gravity is to be taken is placed on one of the scale pans, and on the other pan sufficient known weight is placed to exactly counterbalance it. This will give the weight of the body in the air.

The body is then taken and suspended by a thin wire from the bottom of the scale pan and completely submerged in pure water. When thus submerged the body is counterbalanced by placing weights in the other scale pan and, because of the buoyancy of the water working on the body thus submerged, it will be seen to weigh less in water than in air.

Now, in taking the specific gravity of solids, advantage is taken of the important fact that when a solid is wholly submerged in water it displaces a volume of that liquid exactly equal to its own volume, and the solid appears to lose its weight, that is, it is supported by the surrounding water with a force exactly equal to the weight of the water displaced; hence a body will weigh less in water than in air, and the difference of its weight in water from that of its weight in air must be the weight of an equal volume of water.

For instance, if a piece of glass is found to weigh, in air, 577 grains, and when suspended by a fine wire from the bottom of the scale pan and immersed in a vessel of

pure water it is found to weigh 399.4, the difference between the weight in air (577) and the weight in water (399.4) is the weight of the volume of water displaced by the glass. Therefore:

$$\begin{array}{r} 577.0 \\ \underline{399.4} \\ 177.6 \end{array}$$

is the difference, which difference is the weight of the water displaced.

Hence the rule for finding the specific gravities of solids: Weigh the solid in air and then in pure water (distilled water) and divide the weight of the body in air by the difference between the weights in air and water.

Hence, if a piece of glass is found to weigh 1154 grains in air and 798.8 grains in water, the specific gravity of the glass will be determined by dividing 1154.0 by the difference between 1154.0 and 798.8. Thus:

```
1154.0
 798.8
 -----
 355.2      355.2)1154.0(3.248   Ans.
                  10656
                  -----
                   8840
                   7104
                   -----
                   17360
                   14208
                   -----
                    31520
                    28416
                    -----
```

This shows us, then, that glass is 3.248, etc., times heavier than water. That is, a (cubic inch), for instance, of glass would weigh over three times as much as a cubic inch of water.

Example. If a piece of marble weighs 48.0 grains in air and 31.0 grains in water, what is its specific gravity?

48.0
31.0
17.0 = difference between weight in air and water

17.0)48.0(2.823, etc. *Ans.*
340
1400
1360
400
340
600
510
90

The specific gravities of liquids are ascertained by an instrument called the "Hydrometer."

A Table of Specific Gravities of Liquids and Solids

NAME	SPECIFIC GRAVITY
Air	0.001228
Pure Water	1.0000
Sea Water	1.029
Alcohol	.79
Linseed Oil	0.9347
Olive Oil	0.9176

Solids

Gold	19.3
Lead	11.4
Copper	8.767
Brass	8.384
Cast Iron (Average)	7.110
Wrought Iron (Average)	7.690
Steel	7.780
Tin	7.293
Zinc	7.215

A cubic foot of pure water weighs 62.5 pounds. Therefore, to find the weight of anything contained in the above table, multiply 62.5 (the weight of a cubic foot of pure water) by the specific gravity of the given body.

EXAMPLE. What is the weight of a cubic foot of alcohol?

$$\begin{array}{r} .79 \\ \underline{62.5} \\ 395 \\ 158 \\ \underline{474} \\ 49.375 \text{ lbs.} \quad \textit{Ans.} \end{array}$$

EXAMPLE. What is the weight of 3 cubic feet of alcohol?

$$\begin{array}{rl} .79 & \\ \underline{62.5} & \\ 395 & \\ 158 & \\ \underline{474} & \\ 49.375 & = \text{weight of 1 cubic foot} \\ \underline{3} & \\ 148.125 & = \text{weight of 3 cubic feet} \end{array}$$

EXAMPLE. What is the weight of a cubic foot of cast iron?

$$\begin{array}{r} 7.110 \\ \underline{62.5} \\ 35550 \\ 14220 \\ \underline{42660} \\ 444.3750 \text{ lb.} \quad \textit{Ans.} \end{array}$$

EXAMPLE. What will 2 cubic feet of steel weigh?

```
   7.780
  62.5
  ------
  38900
 15560
46680
-------
486.2500 lb. = weight of 1 cubic foot.
       2
---------
972.5000 lbs.   Ans.
```

EXAMPLE. If one cubic foot of steel weighs 486 pounds, how many cubic feet are there in a ton (2000 pounds)?

```
486)2000 (4.115, etc., cubic feet of steel
    1944                 in a ton
    ----
     560
     486
     ---
      740
      486
      ---
     2540
     2430
     ----
      110
```

EXAMPLE. How much does a cubic foot of wrought iron weigh?

```
  62.5
   7.690
   -----
   56250
   3750
  4375
  --------
  480.6250 lb.   Ans.
```

In practice 480 pounds is called the weight of a cubic foot of wrought iron.

EXAMPLE. How many cubic feet of wrought iron are there in a ton?

$480)2000(4.1\dot{6}$
1920
800
480
3200
2880
3200

$4.1\dot{6}$ cubic feet = 1 ton. *Ans.*

EXAMPLE. What is the weight of a cubic inch of wrought iron?

1 cubic foot = 1728 cubic inches
480 pounds = weight of 1 cubic foot

$1728)480.0(.2\dot{7}$ of a pound. *Ans.*
3456
13440
12096
1344

EXAMPLE. One cubic inch of brass weighs what?

1728)521.75(.313. *Ans.*
5184
3350
1728
6220

EXAMPLE. How many cubic inches of wrought iron weigh 1 pound?

480)1728(3.6 cubic inches = 1 lb.
1440
2880
2880

EXAMPLE. How many cubic inches of fresh water weigh 1 pound?

One cubic foot of fresh water weighs 62.5 pounds.

```
62.5)1728.0(27.656
     1250
     ----
     4780
     4370
     ----
      4100
      3750
      ----
       3500
       3125
       ----
        3750
        3750
        ----
        0000
```

27.656 cubic inches of fresh water = 1 pound. *Ans.*

Example. How much will 2 cubic feet of lead weigh?

```
  62.5
  11.4
  ----
  2500
  625
 625
 ------
 712.50 = weight of 1 cubic foot
      2
-------
1425.00 = weight of 2 cubic feet
```

From the above examples we learn how the weight of anything may be found when its volume and specific gravity are known. Further on examples will be given showing how to find the weight of things whose specific gravity is known, but whose dimensions are given only, by which its volume may be determined, but whose volume is not given.

These examples are given so as to instruct the pupil in figuring the sizes of different parts of machinery, etc., and also to show how to figure the weights of the different parts.

CIRCULAR MEASURE

The diameter of a circle is equal to the circumference divided by 3.1416.

EXAMPLE. What is the diameter of a circle whose circumference measures $12\frac{3}{4}$ inches?

$$12\tfrac{3}{4} = 12.75$$

$$\text{Then } 12.75 \div 3.1416 \text{ is}$$

```
3.1416)12.7500(4.058
       125664
        183600
        157080
         265200
         251328
```

The diameter, then, of a circle whose circumference is $3\frac{3}{4} = 4.058$ inches.

EXAMPLE. A piece of shafting measures $14\frac{1}{4}$ inches around its circumference,— what is its diameter? *Ans.* 4.535, say $4\frac{1}{2}$ inches.

EXAMPLE. What is the diameter of a shaft whose circumference measures $14\frac{1}{4}$ inches? *Ans.* 4.535.

EXAMPLE. What is the diameter of a shaft whose circumference measures 12.5664 inches around? *Ans.* 4 inches.

EXAMPLE. A tube is made of two plates having flanges A, B, as shown in Fig. 33. The outside diameter of tube is 3 feet and each flange measures 4 inches; what is the full length of each plate before being bent?

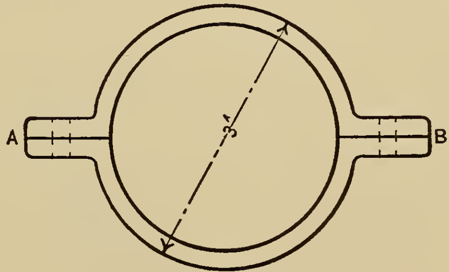


FIG. 33

Reduce first the diameter (3 feet) to inches.

$$\text{Thus } 3 \times 12 = 36 \text{ inches}$$

$$\text{Then} \quad \begin{array}{r} 36 \\ 3.1416 \\ \hline 216 \\ 36 \\ 144 \\ 36 \\ 108 \\ \hline 113.0976 \end{array}$$

equals circumference in inches, to which add the 4 flanges, each of which is 4 inches long, equals 16 inches, then divide by 2, because there are two plates, and the quotient is the length of each plate. Thus:

$$\begin{array}{r} 113.0976 \\ 16 \\ \hline 2\overline{)129.0976} \\ \hline 64.5488 \end{array} \text{ inches} = \text{length of each plate}$$

About 5.379 feet. *Ans.*

Example. The outside diameter of a tube which is made of three plates is 4 feet, each plate has a lap of $1\frac{3}{4}$ inches, what is the full width of each plate? (Fig. 34.)

$$1\tfrac{3}{4} = 1.75$$

$$4 \times 12^{*} = 48 = \text{diameter in inches}$$

$$\begin{array}{r} 48. \\ 3.1416 \\ \hline 288 \\ 48 \\ 192 \\ 48 \\ 144 \\ \hline 150.7968 \end{array} = \text{circumference in inches}$$

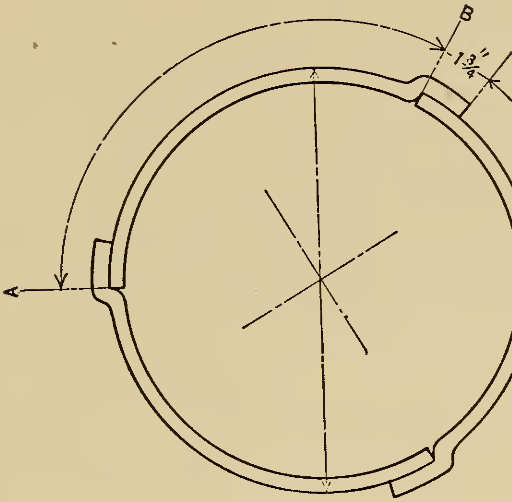


FIG. 34

Now, as this tube is made of three equal sections, the whole circumference divided by 3 will equal the length of each section from A to B, and to this length must be added the length of the laps, $1\frac{3}{4}$ inches, and the sum will equal the whole width of each plate.

Thus: $\dfrac{150.7968}{3} + 1.75 = 52.0156$ inches. *Ans.*

EXAMPLE. What is the full length in inches of a brass band, $\frac{1}{4}$ inch thick, which goes around a funnel whose diameter is $5\frac{1}{4}$ feet? The end of the band laps 3 inches. (Fig. 35.)

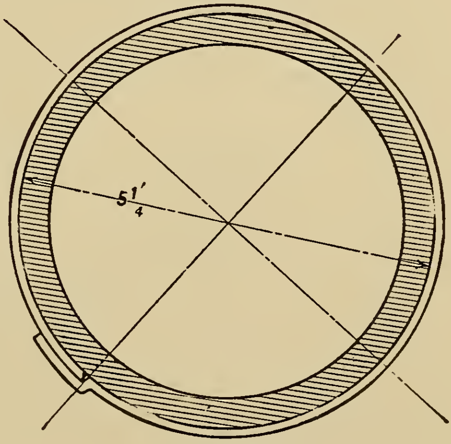


FIG. 35

$$5\tfrac{1}{4} = 5.25$$

$5.25 \times 12 \times 3.1416 = 197.920$ circumference in inches of strap.

Then $197.920 + 3 = 200.920$ inches, or 16.743 feet.

Example. If a circular plate, 5 feet in diameter, has to have some holes bored in it, $2\frac{1}{4}$ inches from the edge of the plate to the center of the holes, what will be the diameter of the circle on which holes are bored? (Fig. 36.)

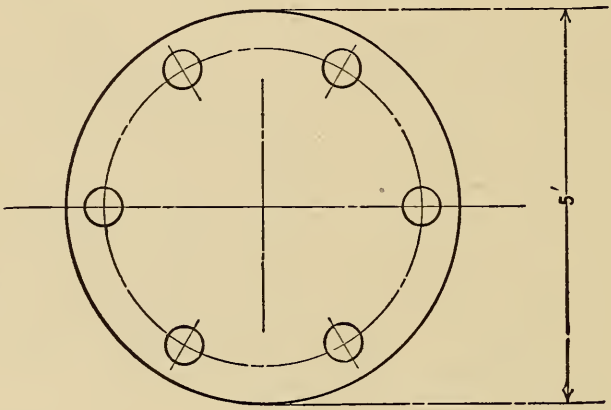


Fig. 36

The circle on which the holes are bored is $2\frac{1}{4}$ inches inside the outer diameter of plate, and therefore five inches less in diameter. Diameter of plates = 5 feet = 60 inches

Then $60 - 5 = 55$ inches. *Ans.*

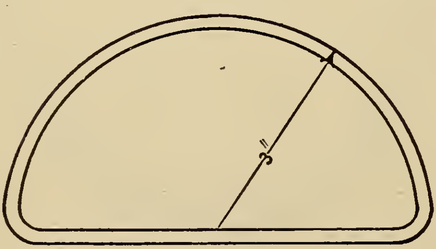


Fig. 37

Example. What is the full length around and across the base of an arched piece of metal like Figure 37. The arch equals $\frac{1}{2}$ circle.

Divide circumference of

circle, whose radius is 3 inches (diameter 6 inches) by 2, to which add 6 inches (distance across base).

$$\text{Thus } \frac{3.1416 \times 6}{2} + 6 = 15.4248 \text{ inches.} \quad \textit{Ans.}$$

EXAMPLE. What is the outside circumference of a ring whose outside diameter is 4 feet?

And what is the inside circumference when the diameter is $2\frac{1}{2}$ feet, and what width of ring? (Fig. 38.)

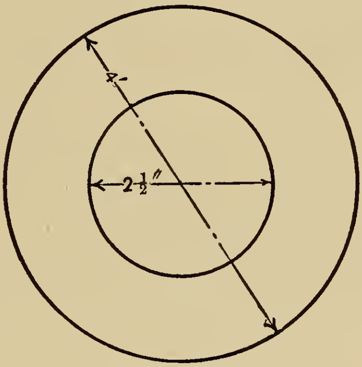


FIG. 38

$$3.1416 \times 4 \quad = 12.5664 \text{ feet, outside circumference}$$
$$3.1416 \times 2.5 = \ 7.85400 \text{ feet, inside circumference}$$
$$4 - 2.5 = 1.5 \div 2 = .75 \text{ feet, width of ring.} \quad \textit{Ans.}$$

EXAMPLE. The circumference of a flange is 60 inches and in it there are a number of holes 4 inches from the outside of flange to center of holes. What is the diameter of circle on which holes are drilled? (Fig. 39.)

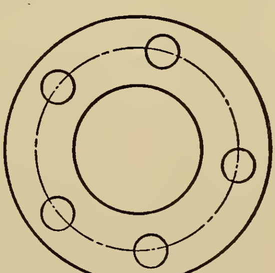


FIG. 39

The first thing we do is to find the diameter of the flange, from which we subtract twice the distance from the outside of flange to center of holes.

$$\text{Thus } \frac{60}{3.1416} - 4 \times 2 = \quad Ans.$$

```
3.1416)60.0000(19.095 = diameter of flange
       31.416
       285840
       282744
         309600
         282744
          16856
```

$$19.095 - 8 = 11.095. \quad Ans.$$

Then 11.095 is the diameter of circle on which holes are drilled.

Square Measurements

Note: one dash after a dimension represents feet
Thus 23′ = 23 feet, and 6′ = 6 feet
And two dashes after a dimension represents inches.
Thus 23″ = 23 inches, and 6″ = 6 inches

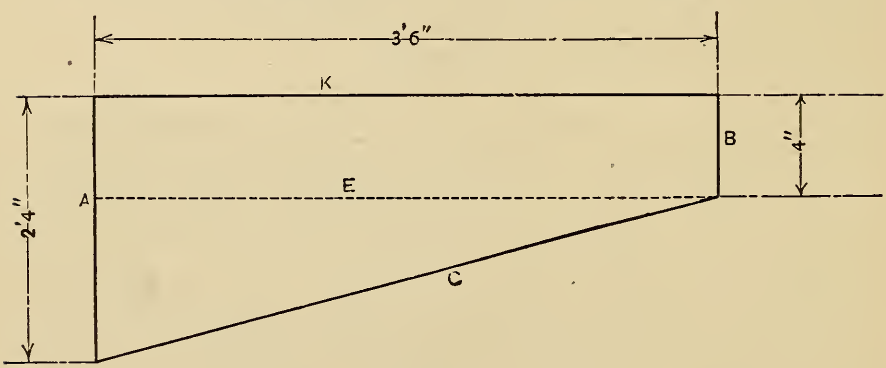


Fig. 40

Example. Find the surface in square feet, of a sheet of metal of the following dimensions. (Fig. 40.)

This may be done by adding the ends A and B together and dividing by 2, which will give the mean width, which multiply by the length, 3′, 6″.

$$\text{Thus } \frac{2'\,4'' + 4''}{2} = \frac{32''}{2} = 16 \text{ mean width}$$

Thus $16 \times 3'\,6'' = 16 \times 42'' = 672$ square inches, or 4.6 square feet, or it may be done by adding together the area of the triangle, A, E, C, and the area of the parallelogram, A, E, B, K.

Thus the triangle $= \dfrac{2' \times 3'\,6''}{2}$, or $\dfrac{24'' \times 42''}{2} = 504$ square inches.

And the parallelogram $= 4'' \times 42'' = 168$ square inches

144 square inches = 1 square foot

$$\begin{array}{ll} \text{Then} & 504 \\ \text{And} & \underline{168} \\ & 672 \text{ sq. in., or 4.6 sq. ft. } \quad \textit{Ans.} \end{array}$$

$$\begin{array}{r} 144)672(4.6 \\ \underline{576} \\ 960 \\ \underline{864} \\ 96 \end{array}$$

EXAMPLE. Find the measurement in square feet, of a sheet of metal of the following dimensions. (Fig. 41.) Answer: $10\frac{1}{2}$ square feet.

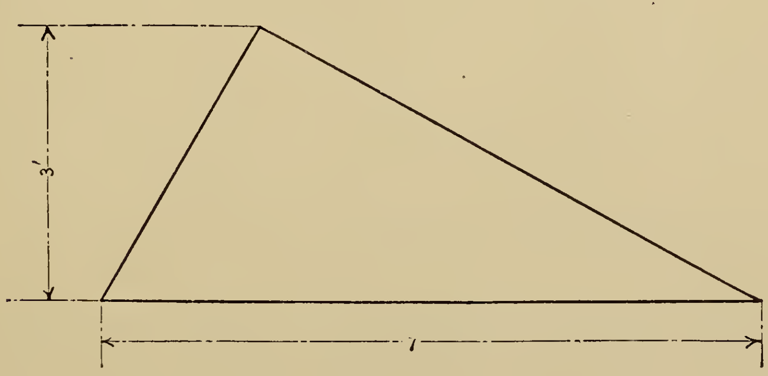


FIG. 41

$$\frac{7 \times 3}{2} = 10\tfrac{1}{2} \quad \textit{Ans.}$$

EXAMPLE. What is the area of a sheet of metal of the following shape and dimensions. (Fig. 42.) Answer: 88.3575 square inches.

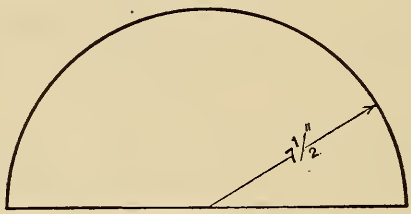


FIG. 42

$$\frac{15'' \times 15'' \times .7854}{2} = 88.3575 \text{ square inches.} \quad \textit{Ans.}$$

The area of the whole circle would equal 176.7150 square inches, therefore the plate being ½ circle equals 88.3575 square inches.

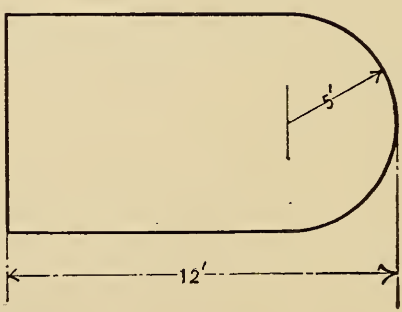


FIG. 43

EXAMPLE. What is the area of a sheet of metal of the above shape and dimensions. (Fig. 43.)

The circular end of plate equals ½ circle.

Thus

$$\begin{array}{r} 5 \\ \underline{5} \end{array}$$

$$\frac{25 \times .7854}{2} = 9.8125 \text{ sq. ft.}$$

Find now the area of the remainder of the sheet, which add to (9.8125) the area of the circular part.

Thus 9.8125 + 70 = 79.8125 sq. ft. *Ans.*

EXAMPLE. Find the surface in square feet of a piece of plate of the following dimensions. (Fig. 44.)

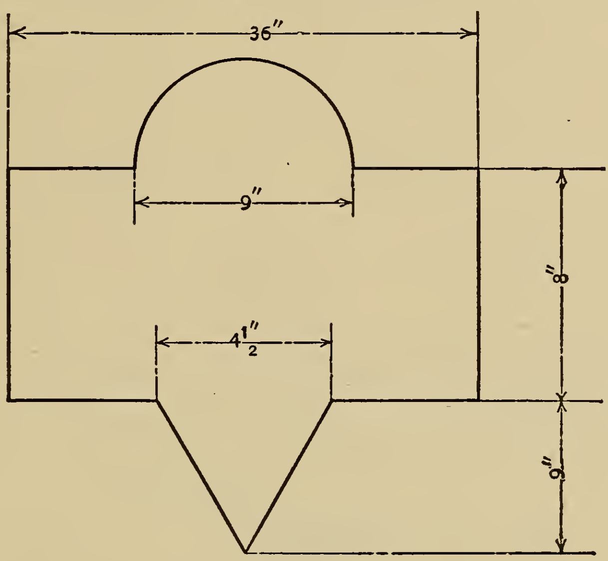


FIG. 44

31.8087 ≐ Area of curved part.
288 = oblong part.
20.25 = triangular part.

Thus 31.8087 + 288 + 20.25 = 340.058 square inches., or 2.361 square feet. *Ans.*

EXAMPLE. What is the number of square inches in the outside surface of a cylinder whose outside diameter is 5 inches and height 15 inches. (Fig. 45.)

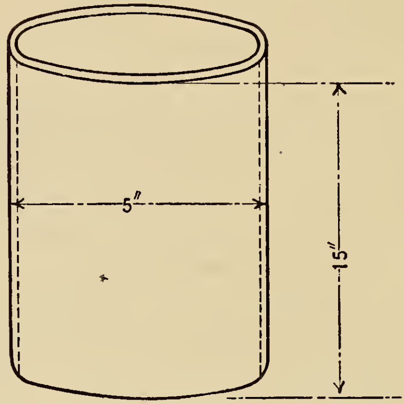


FIG. 45

$$\begin{array}{r l}
3.1416 & \\
5 & \\
\hline
15.7080 & = \text{circumference} \\
15 & = \text{height} \\
\hline
785400 & \\
157080 & \\
\hline
235.6200 & \text{sq. in.} \quad \textit{Ans.}
\end{array}$$

EXAMPLE. What is the number of square inches in the outside surface of an elliptical tube whose diameters are 2 and 4 inches and whose length is 12 inches? (Fig. 46.)

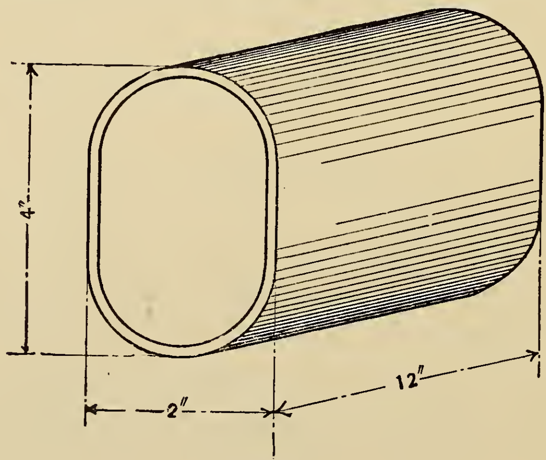


FIG. 46

$$\begin{array}{rl} 3.1416 & \\ 3 & = \text{half sum of diameters} \\ \hline 9.4248 & = \text{circumference} \\ 12 & \\ \hline 113.0976 & \text{sq. in.} \quad \textit{Ans.} \end{array}$$

Circular Areas

Example. Find the area of metal in a ring whose outer diameter is 13 inches and inner diameter 9 inches. (Fig. 47.)

First find the area of the outer diameter. Next find the area of the inner diameter. Then their difference is the required area of metal.

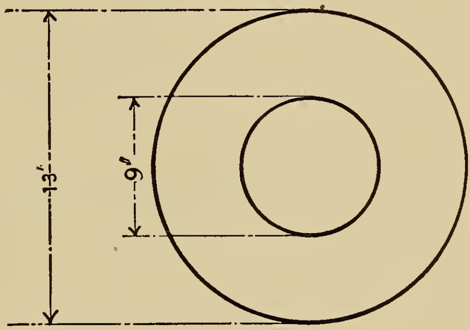


Fig. 47

Thus $13 \times 13 \times .7854 = 132.7326$, area of large diameter.
and $9 \times 9 \times .7854 = \underline{63.6174}$, area of small diameter.
Difference, 69.1152, area of metal.

Example. What area of metal is there in a section of a round bar of iron 3 inches in diameter? (Fig. 48.)

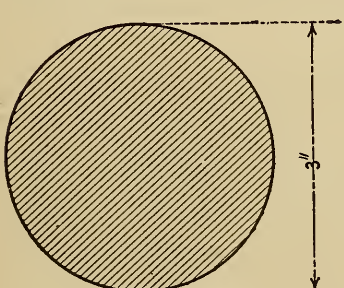


Fig. 48

$$\begin{array}{r} 3 \\ 3 \\ \hline 9 \end{array}$$

$$.7854 \times 9 = 70.686 \text{ area}$$

Example. What area of metal is there in a section of a tube whose inside diameter is 5 inches and the thickness of tube is $\frac{1}{4}$ inch? (Fig. 49.)

In this case, as the inner diameter is 5 inches and the tube is $\frac{1}{4}$ inch thick, the outside diameter must be $5'' + \frac{1}{4} + \frac{1}{4} = 5.5$.

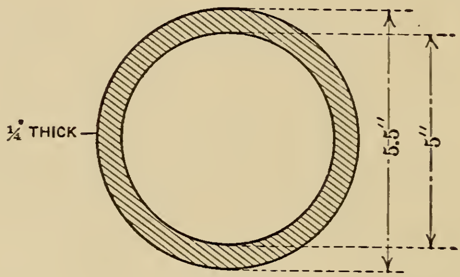


Fig. 49

Now find the difference between the two areas.

$$
\begin{array}{r}
5 \\
\underline{5} \\
25 \times .7854 = 19.6350 \quad \text{area of inside diameter.}
\end{array}
$$

$$
\begin{array}{l}
5.5 \\
\underline{5.5} \\
275 \\
\underline{275} \\
30.25 \times .7854 = 23.758350 \quad \text{area of outside diameter.} \\
 \underline{19.6350} \\
 4.123350 \text{ area. } \textit{Ans.}
\end{array}
$$

Example. The inner diameters of an elliptical tube are 3 feet and 4 feet, and the thickness of metal is $\frac{1}{4}$ inch, what area of metal is there in a section of the tube? (Fig. 50.)

As the inner diameters are 3 feet and 4 feet, that is, 36 inches and 48 inches, and the metal is $\frac{1}{4}$ inch thick, the outside diameters must be

Conguatt axis (outside) $\frac{1}{4} + 36 + \frac{1}{4} = 36\frac{1}{2} = 36.5$ inches
Transverse axis (outside) $\frac{1}{4} + 48 + \frac{1}{4} = 48\frac{1}{2} = 48.5$ inches
Inside diameters 3 feet $= 36$ inches
And 4 feet $= 48$ inches

Find the difference between the two areas and the answer is the area of metal in a section of the tube.

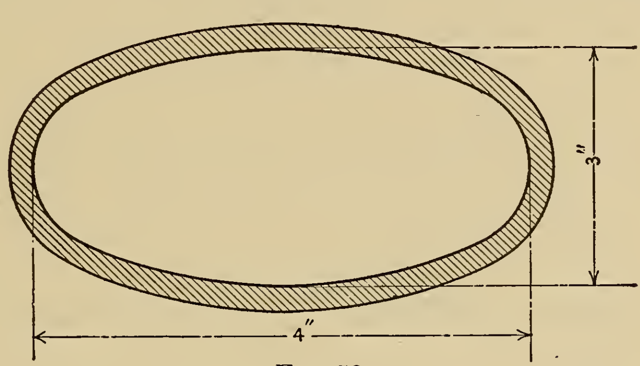


Fig. 50

$$
\begin{aligned}
36.5 \times 48.5 \times .7854 &= 1390.354 \\
36 \times 48 \times .7854 &= \underline{1356.971} \\
\textit{Ans.} &= 33.383
\end{aligned}
$$

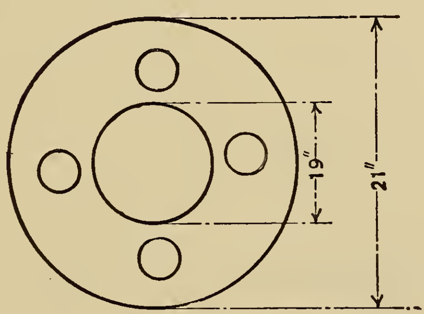


Fig. 51

Example. If the outer diameter of a metal ring is 21 inches and the inner diameter is 19 inches, and the ring has 4 quarter-inch holes in it, what is the area ot the metal? (Fig. 51.)

First find the area enclosed by the outer diameter, which is 346.3614 square inches.

Next find the area enclosed by the inner diameter which is 283.5294 square inches. Then find their difference. Thus:

$$\begin{array}{r} 346.3614 \\ \underline{283.5294} \\ 62.8320 \end{array}$$

From which subtract the sum of the areas of the four $\frac{1}{4}$-inch holes and the difference is the required area, $\frac{1}{4} = .25$.

$$\begin{array}{rl} .25 & \\ \underline{.25} & \\ 125 & \\ 50 & \\ \hline .0625 & \\ \underline{.7854} & \\ 2500 & \\ 3125 & \\ 5000 & \\ 4375 & \\ \hline .04908750 & = \text{area of } \tfrac{1}{4}'' \text{ hole} \\ \underline{4} & \\ .19635000 & = \text{area of 4 holes} \end{array}$$

$$\begin{array}{rl} 62.8320 & \\ \underline{.1965000} & \\ 62.6355 & = \text{area in sq. in. of metal.} \quad \textit{Ans.} \end{array}$$

To Find the Diameter of a Circle when the Area is Given

Rule. Divide area by .7854, then find the square of the quotient obtained, which will equal the diameter.

Example. What is the diameter of a circle whose area is 190.0668 square inches?

```
.7854)190.0668(242
      15708
      ─────
       32986
       31416
       ─────
        15708
        15708            2,42(15.5
        ─────            1
                         ──
                       25)142
                          125
                          ───
                      305)1700
                          1525
                          ─────
                           17500
                     15.5 etc. inches.   Ans.
```

EXAMPLE. If the area of a shaft is 3.1416 square inches, what is its diameter?

```
.7854)31416(4      4(2 inches.  Ans.
      31416        4
      ─────        ─
```

EXAMPLE. If the area of a shaft is 6.2832 square inches, what is its diameter?

```
.7854)62832(8         8(2.828 etc.
      62832            4
      ─────           ──
                   48)400
                      384
                      ───
                  562)1600
                      1124
                      ─────
                 5648)47600
                      45184
                      ─────
```

EXAMPLE. If the area of a circular plate is 706.86 squáre inches, what is its diameter? *Ans.* 30 inches.

NOTE. The diameter of a circle equals the square root of the area multiplied by 1.12838. However, the diam-

eter is determined usually when the area is given by the process worked out in the example.

Measurements and Weights of Tanks. Examples Showing how to find the Cubic Capacity and Weight of Rectilinear and Circular Vessels and Tanks

Note. The U. S. Standard gallon measures 231 cubic inches and contains $8\frac{1}{3}$ pounds of distilled water (pure water). A cubic foot of water (fresh) weighs $62\frac{1}{2}$ pounds and contains 1728 cubic inches, or nearly $7\frac{1}{2}$ gallons U. S. standard.

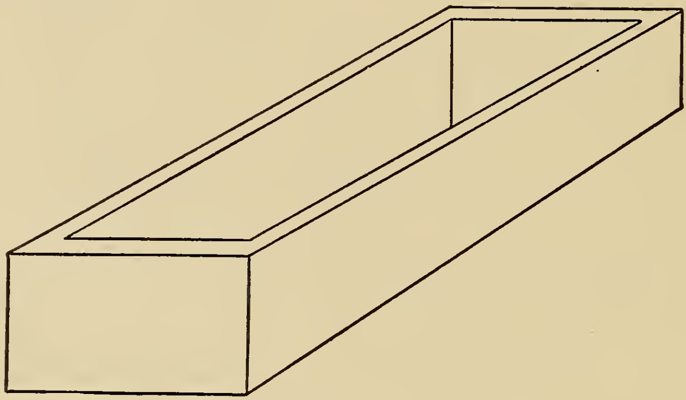


Fig. 52

Rule. To find the capacity of four-sided vessels in gallons, find the cubical contents by multiplying the length, breadth, and height in inches, and divide the product by 231.

Example. If the inside dimensions of a tank are 4 feet wide, 3 feet deep, and 12 feet long, how many gallons of water will it hold? (Fig. 52.)

$$3 \text{ feet} = 36 \text{ inches.}$$
$$4 \text{ feet} = 48 \text{ inches.}$$
$$12 \text{ feet} = 144 \text{ inches.}$$

Then $36 \times 48 \times 144 = 248832$ cubic inches.

```
231)248832(1077, etc., gallons.
    231
    ----
     1783
     1617
     ----
      1662
      1617
      ----
```

EXAMPLE. How many gallons will a tank of the following dimensions hold: 5 feet long, 4 feet deep, 9 feet wide?

5 feet = 60 inches.
4 feet = 48 inches.
9 feet = 108 inches.

Then $60 \times 48 \times 108 = 311040$ cubic inches.

```
231)311040(1346.49 gallons.
    231
    ---
     800
     693
     ----
     1074
      924
      ----
      1500
      1386
      ----
       1140
        924
        ----
        2160
        2079
        ----
```

1346, etc., gallons. *Ans.*

EXAMPLE. How many gallons of oil will a tank 9 feet 3 inches long, 4 feet 5 inches wide, and 6 feet 2 inches deep, hold?

9 feet 3 inches = 111 inches.
4 feet 5 inches = 53 inches.
6 feet 2 inches = 74 inches.

Then $111 \times 53 \times 74 = 435342$ cubic inches.

$$
\begin{array}{r}
231)435342(1884.597 \text{ gallons.} \\
\underline{231}\phantom{000(1884.597 \text{ gallons.}} \\
2043\phantom{00(1884.597 \text{ gallons.}} \\
\underline{1848}\phantom{00(1884.597 \text{ gallons.}} \\
1954\phantom{0(1884.597 \text{ gallons.}} \\
\underline{1848}\phantom{0(1884.597 \text{ gallons.}} \\
1062\phantom{(1884.597 \text{ gallons.}} \\
\underline{924}\phantom{(1884.597 \text{ gallons.}} \\
1380\phantom{(1884.597 \text{ gallons.}} \\
\underline{1155}\phantom{(1884.597 \text{ gallons.}} \\
2250 \\
\underline{2079} \\
1710 \\
\underline{1617} \\
93
\end{array}
$$

1884, etc., gallons. *Ans.*

Example. What weight of water is there in a tank of the dimensions of the preceding example?

As 1 gallon of water weighs $8\frac{1}{3}$ pounds, 1884 gallons will weigh $1884 \times 8\frac{1}{3}$.

$$
\begin{array}{r}
1884 \\
\underline{8.\dot{3}} \\
5652 \\
\underline{15072} \\
15637.2
\end{array}
$$

15637, etc., lbs. = weight. *Ans.*

The best process, perhaps, for determining the weight of the contents of tanks is to multiply the cubic contents in feet by the weight of a cubic foot of the contents.

EXAMPLE: What will be the weight of fresh water in a tank, when full, of the following dimensions: 5 feet long, 4 feet wide, 9 feet deep?

$$5 \times 4 \times 9 = 180 \text{ cubic feet.}$$

Then as 1 cubic foot of fresh water weighs 62.5 pounds, $180 \times 62.5 =$ weight of 180 cubic feet of fresh water.

Thus
$$\begin{array}{r} 180 \\ 62.5 \\ \hline 900 \\ 360 \\ 1080 \\ \hline 11250.0 \end{array} = \text{weight.}$$

11,250.0 lb. *Ans.*

EXAMPLE. A tank 5 feet long, 4 feet wide, and 9 feet deep, will hold how many pounds of sea water?

One cubic foot of sea water = 64.3 lb.

$$5 \times 4 \times 9 = 180 \text{ cubic feet.}$$

Then $180 \times 64.3 = 11{,}574.0$ lb. weight.

EXAMPLE. What will a tank of linseed oil of the following dimensions weigh: 5 feet deep, 4 feet wide, and 9 feet long?

$$5 \times 4 \times 9 = 180 \text{ cubic feet.}$$

$$\begin{array}{lr} \text{Specific gravity of linseed oil} = & 0.9347 \\ & 62.5 \\ \hline & 46735 \\ & 18694 \\ & 56082 \\ \hline \text{Weight of cubic foot of oil} = & 58.41875 \end{array}$$

$180 \times 58.418 = 10{,}515.240$ lb. *Ans.*

EXAMPLE. How many pounds of linseed oil will a tank 5 feet 2 inches by 4 feet 5 inches, and 2 feet 5 inches deep, hold?

Reduce all dimensions to inches. We then have

$$62 \times 53 \times 29 = 95.294 \text{ cubic inches}$$

and 95.294 cubic inches = 55.14, etc., cubic feet.

Then 55.14 etc.

```
       58.418 weight of cubic foot of linseed oil
     --------
       44112
       5514
     22056
    44112
   27570
  ----------
  3221.16852 lb.
```

3221 lb. *Ans.*

Measurements of Circular Tanks

Example. How many cubic feet of space in a cylindrical tank whose diameter is 25 inches and height 12 inches? (Fig. 53.)

This is the same as finding the volume of a cylinder.

```
 25 diam.
 25
---
125                        .7854
50                           625
---                        -----
625 diam. squared.         39270
                          15708
                         47124
                         ---------
                         490.8750 area of base.
                               12 inches high.
                        ----------
                        5890.5000 cubic inches in volume.
```

Then $5890.5000 \div 1728 = 3.408$ cubic feet. *Ans.*

Example. If the above cylinder is filled with linseed oil, what will be its weight?

1 cubic foot of linseed oil weighs 58.418 pounds.

```
     58.418
      3.408
     ------
     467344
   233672
 175254
 ----------
 199.088544
```

199 lb. *Ans.*

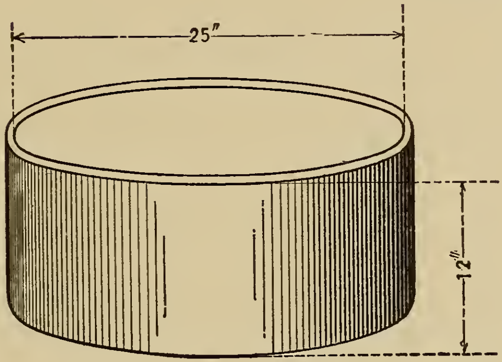


FIG. 53

How many gallons will the above cylinder hold? (Fig. 53.)

TO FIND THE CAPACITY OF CYLINDRICAL VESSELS IN GALLONS.

RULE. Multiply the area in inches by the height in inches and divide product by 231.

$25 \times 25 \times .7584 \times 12 = 5890.5000$ area in inches.

```
231)5890.5000(25.5 gallons.   Ans.
    462
    ----
    1270
    1155
    -----
     1155
     1155
     ----
```

EXAMPLE. How many cubic feet, and what will be the weight of, and how many gallons of water will a tank of the following dimensions hold: diameter 43 inches, and height 24 inches?

$43 \times 43 \times .7854 \times 24 = 34852.9104$ cubic inches.
Then $34852.9104 \div 1728 = 20.111$ cubic feet.
Weight equals $20.111 \times 62.5 = 1256.937$ lb.

Now we can find the number of gallons contained in the tank by either dividing 34852.9104 cubic inches, which is its contents in cubic inches, by 231, because there are 231 cubic inches in a gallon.

Thus $34852.9104 \div 231 = 150.878$ gallons.
(Almost 151 gallons.)

Or we can find the number of gallons contained in the tank by multiplying its cubic contents in feet (20.111) by $7\frac{1}{2}$, because there are $7\frac{1}{2}$ gallons in one cubic foot.

$$
\begin{array}{lr}
\text{Thus} & 20.111 \\
 & 7.5 \\
\hline
 & 100555 \\
 & 140777 \\
\hline
 & 150.8325
\end{array}
\text{ gallons. } \textit{Ans.}
$$

EXAMPLE. How many gallons of water will a tank having the following dimensions hold: base diameter 5 feet, top diameter 3 feet, and height, 4 feet? (Fig. 54.)

This is the first example of a frustum-shaped tank we have had, and the process for determining the cubic contents of a frustum was explained in Mensuration.

First find cubic contents in inches, then reduce cubic contents in inches to cubic feet, and multiply by 7.5; product will be required answer.

$36 \times 36 \times .7854 = 1017.8784$ area in inches of top diameter.

And $60 \times 60 \times .7854 = 2827.4400$ area in inches of bottom diameter.

$3845.3184 =$ sum of areas of both bases.

$16 = \frac{1}{3}$ of perpendicular height in inches.

230719104
38453184

$61525.0944 =$ area in cubic inches.

$61525.0944 \div 1728 = 35.604$ cubic feet. *Ans.*

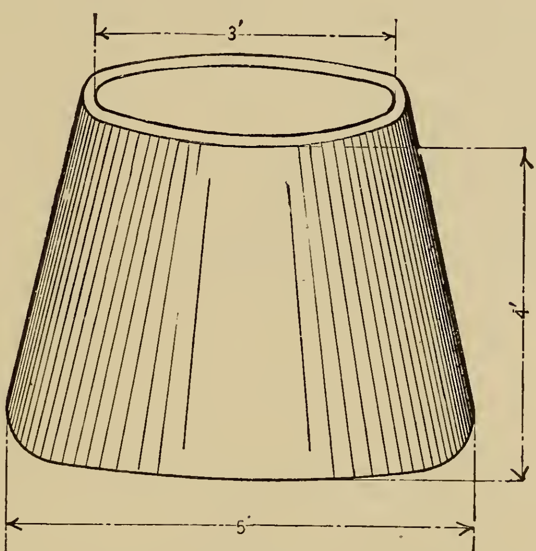


FIG. 54

EXAMPLE. How many gallons will the above tank hold?

$35.604 \times 7.5 = 267.03$ gallons.

Examples Explaining how to Calculate the Weight of Different Materials and the Weight of the Different Parts of a Machine

Examples coming under this head will now offer very little difficulty in solving.

To find the weight of any body, we proceed first by finding its area, and having obtained the area the weight is found by multiplying the weight of a cubic foot of the material by the area in feet. Or, if the area is given in inches, the weight will be found by multiplying the area in inches by the weight of a cubic inch of the material.

Example. What is the weight of a cast-iron plate of the following dimensions? 4′ wide 6″ thick and 8′ long. (Fig. 55.)

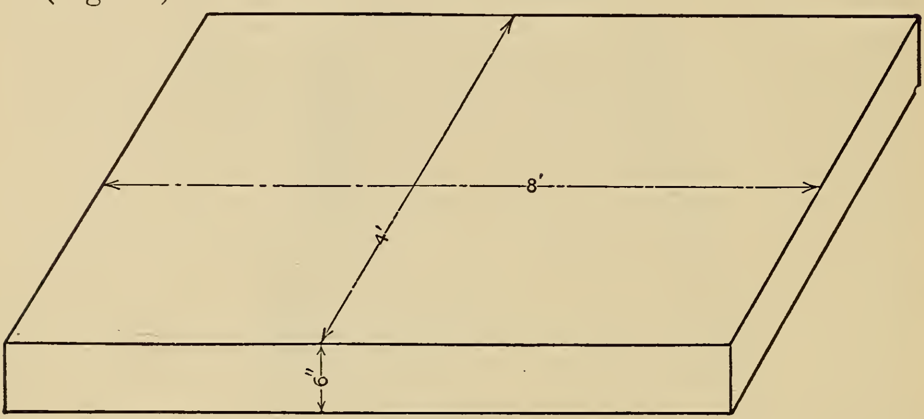


Fig. 55

$$4 \text{ feet} = 48 \text{ inches.}$$
$$6 \text{ inches} = 6 \text{ inches.}$$
$$8 \text{ feet} = 96 \text{ inches.}$$

$$\text{Then } 48 \times 6 \times 96 = 27648 \text{ cubic inches area}$$

The specific gravity of cast iron being 7.110 the weight, of a cubic foot of cast iron will equal

$$7.110 \times 62.5 = 444.3750 \text{ lb.}$$

And since a cubic foot weighs 444.3750 pounds, a cubic inch will equal 444.3750 ÷ 1728 = .257 lb.

Then, since one cubic inch equals .257, the weight of 27648 cubic inches is 27648 × .257 = 7105.536 lb.

Answer: About 7105½ pounds will be the weight of the plate.

Example. What is the weight of a cast-iron plate of the following dimensions? (Fig. 56.)

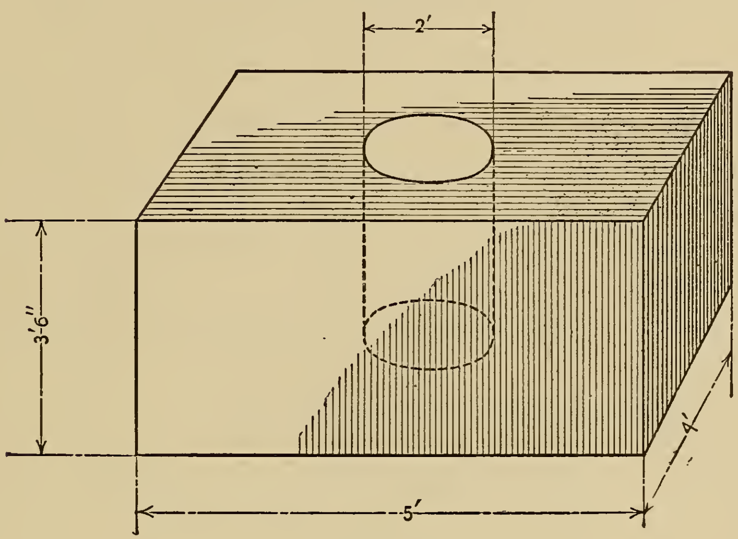


Fig. 56

3 feet 6 inches = 42 inches.
5 feet = 60 inches.
4 feet = 48 inches.

First find the area in cubic inches of whole piece.

Then find the area of the whole, and subtract the latter from the former, and the answer will be the area in cubic inches of iron in the plate.

Then multiply the area thus obtained by .257 (the weight of a cubic inch of cast iron) and the product will equal the weight. Thus:

60″ × 48″ × 42″ = 120.960 cu. inches area of plate.
24″ × 24″ × .7854 × 42″ = 19.000 cu. inches area of hole.
Difference 101.960 number of cu. inches in plate.
.257 weight of cu. inches of cast iron.

713720
509800
203920

26103.720 weight of plate.

26.103 pounds equals weight of plate. *Ans.*

EXAMPLE. What will be the weight of a cast-iron column 20 feet long, outside diameter 14 inches, and inside diameter 8 inches? (Fig. 57.)

6397½ lb. *Ans.*

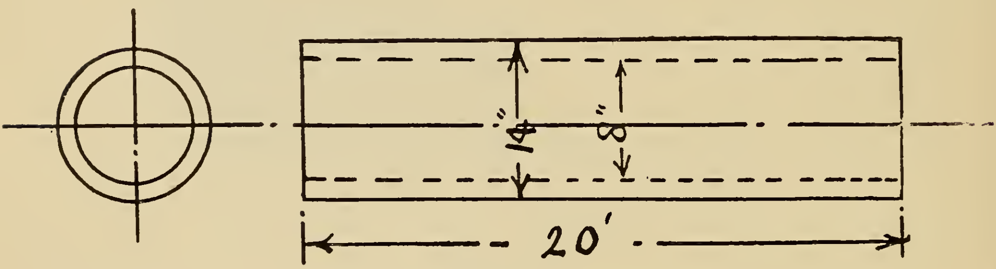


FIG. 57

14″ × 14″ × .7854 × 240″ = 36945 etc., area in in. of outside diameter.
8″ × 8″ × .7854 × 240″ = 12063 etc., area in inches of inside diameter.
Difference 24882 = number of cu. inches of iron.

Then 24882 × .257 = 6394.674 lb.

About 6397½ pounds weight of column. *Ans.*

EXAMPLE. What is the weight of a wrought-iron

shaft having two flanges, one of which is $3\frac{3}{4}$ inches thick and 1 foot 5 inches diameter, the other $2\frac{1}{2}$ inches thick and 1 foot $4\frac{1}{2}$ inches diameter, the shaft is $5\frac{1}{2}$ inches diameter and 14 feet 2 inches over all? (Fig. 58.)

1475.327544 etc. lb. *Ans.*

$17 \times 17 \times .7854 \times 3.75 = 851.1772$ area of flange 1.
$16.5 \times 16.5 \times .7854 \times 2.5 = 534.5628$ area of flange 2.
$170'' - 3.75'' - 2.5'' = 163.75''$ ($163\frac{3}{4}''$) length of shaft.
$5.5 \times 5.5 \times .7854 \times 163.75 =$ area of shaft part.

5.5		
5.5	8511772	
275	5345628	
275	38904298	
3025	5276.1698	= whole area in inches.
.7854	.28	= weight of cubic inch of
12100	420093584	wrought iron.
15125	105523396	
24200	1475.327544 lb.	= weight.
21175		
23.758350		
163.75		
118791750		
166308450		
71275050		
142550100		
23758350		
3890.42981250		= area in inches of shaft part.

In the above example we first find the area of flange 1 then the area of flange 2. We then find the area of the whole shaft minus the two flanges. The three areas are then added together and the sum thus found is the whole area of shaft, which multiplied by the weight of a cubic

inch of wrought iron will give the whole weight of the shaft.

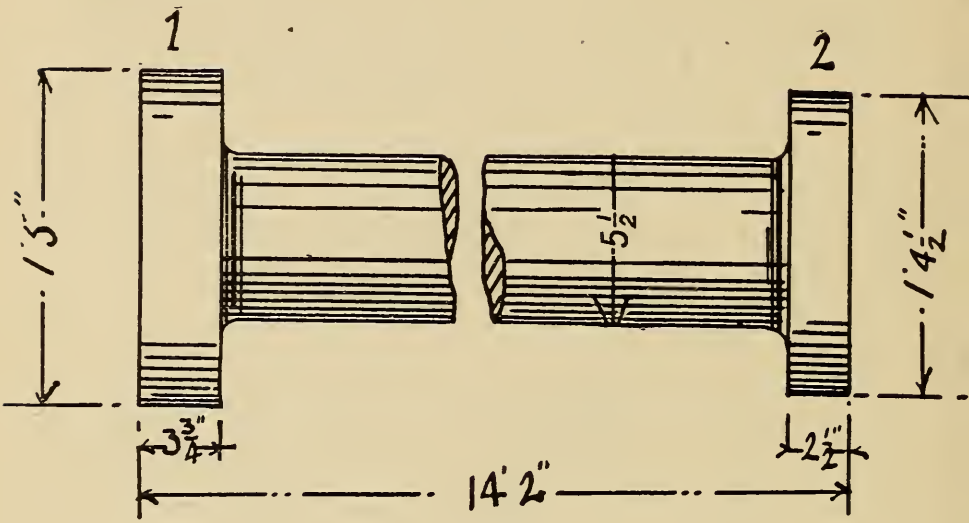


Fig. 58

The weight of a cubic inch of wrought iron is obtained by multiplying 7.690, the specific gravity of wrought iron, by 62.5, the weight of a cubic foot of water (fresh). The product is the weight of a cubic foot of wrought iron, which, divided by 1728, gives the weight of a cubic inch, .285.

Example. A circular brass plate is 6 feet 5 inches in diameter, 4 inches thick, and has five 4-inch holes in it. (Fig. 59.) What will it weigh?

5512.565 lb. *Ans.*

$77 \times 77 \times .7854 \times 4 =$ 18626.5464 area of whole plate in cubic inches.

$4 \times 4 \times .7854 \times 4 =$ 50.2656 area of one hole in cubic inches.

$$\begin{array}{r} 5 \\ \hline 251.3280 \end{array}$$

= area of five holes in cubic inches.

Then 18626.5464 − 251.3280 = 18375.2184 etc., whole area minus area of holes.

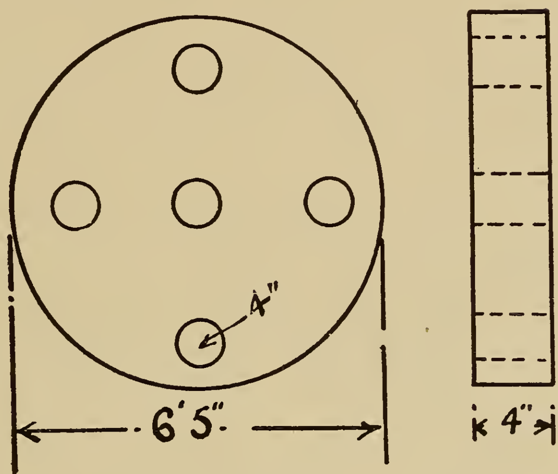


FIG. 59

Specific gravity of brass equals 8.384.
Then brass per cubic foot equals 8.384 × 62.5 = 524 lb.
Hence the weight per cubic inch is 524 ÷ 1728 = .3 lb.
Then the weight of 18375.2184 cubic inches is

18375.2184 × .3 = 5512.565 lb. *Ans.*

EXAMPLE. What is the weight of a brass cylinder whose inside diameter is 10 inches, the brass being ½ inch thick and the cylinder 3 feet 5 inches long? (Fig. 60.)

202.8 etc. lb. *Ans.*

10 × 10 × .7854 × 41 = 3220.1400 area of inside diam.
½ + 10 + ½ = 11 outside diameter.

Then 11 × 11 × .7854 × 41 = 3896.3694 area of outside diameter.

Then area of outside diameter minus area of inside diameter equals area of metal.

Thus 3896.3694 − 3220.1400 = 676, etc.

Then as one cubic inch of brass weighs .3 of a pound, 676 cubic inches weighs

$$\begin{array}{r} 676 \\ .3 \\ \hline 202.8 \end{array}$$ lb. *Ans.*

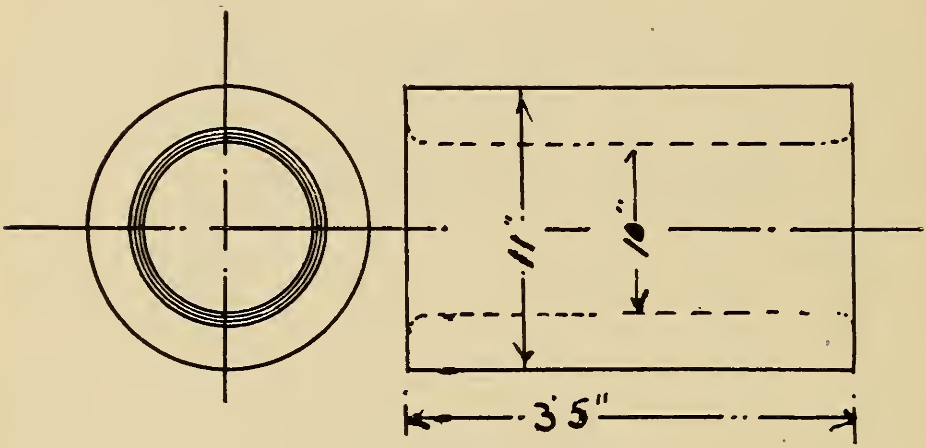


Fig. 60

Example. What is the weight of a brass cylinder whose length is 45 inches, outer diameter 12 inches, and thickness $\frac{3}{4}$ inch? (Fig. 61.)

357.84 lb. *Ans.*

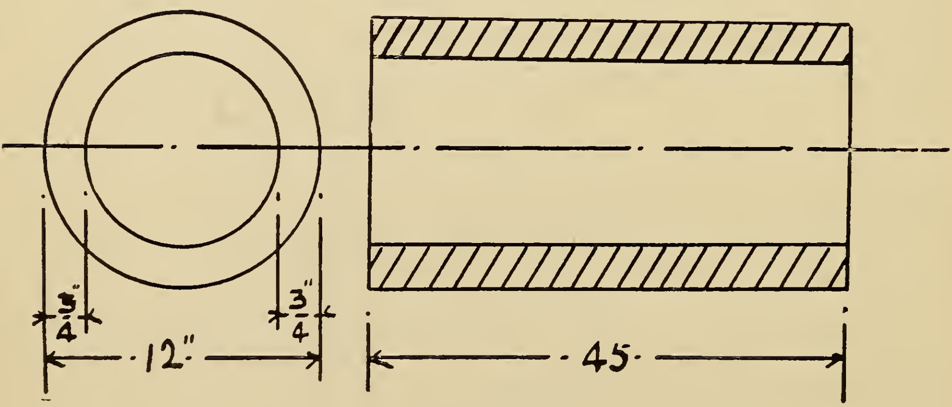


Fig. 61

Inner diameter equals $12 - \frac{3}{4} - \frac{3}{4} = 10.5$

$12 \times 12 \times .7854 \times 45 = 5089.39$ cu. in. of metal in outside diameter.

$10.5 \times 10.5 \times .7854 \times 45 = 3896.56$ cu. in. of metal in inside diameter.

Then $5089.39 - 3896.56 = 1192.83$ cubic inches of metal.

Hence $1192.83 \times .3 = 357.84$ lb. weight.

EXAMPLE. Find the weight of the rim of a cast-iron fly-wheel whose outer diameter is 9 feet 6 inches, and inner diameter 9 feet 3 inches, and 12 inches wide. (A cubic inch of cast iron equals .257 of a pound.) (Fig. 62.)

1634.9 lb. *Ans.*

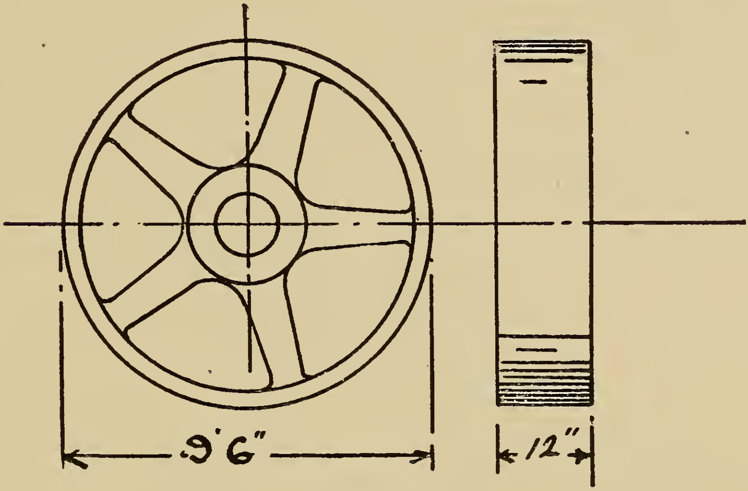


FIG. 62

$114 \times 114 \times .7854 \times 12 = 122484.700$ cu. in. of metal in outside diam.

$111 \times 111 \times .7854 \times 12 = 116122.960$ cu. in. of metal inside diam.

Then 122484.700 minus 116122.960 equals 6361.740 cubic inches of iron in rim.

Hence $6361.740 \times .257 = 1634.9$ etc. lb., weight. *Ans.*

Example. Find the weight of the rim of a fly-wheel whose outer diameter is 10 feet 9 inches, and inner diameter 8 feet 2 inches, and width 8 inches.

11363.2 etc. lb. *Ans.*

Example. What is the weight of a cast-iron cap of the following dimensions, if a cubic inch of cast iron weighs .257 of a pound? (Fig. 63.)

First find the weight of the flanges A and B, then find the weight of cap, and the sum of both weights equals whole weight.

Flanges.

$6 \times 2 \times 36 \times 2$

2
12
36
72
36
432
2 = flanges.
864 area in cu. in of flanges.

Outside Dimension.

$20 \times 9 \times 36$

9
180
36
1080
540
6480
4032
2448 area in cu. in. cap.

Inside Dimensions.

$16 \times 7 \times 36$

7
112
36
672
336
4032

Then $2448 + 864 \times .257 =$ weight.

864
3312
.257
23184
16560
6624
851.184 lb. *Ans.* (About 852 lbs.)

Note.—Width of flange from A to C = 6″

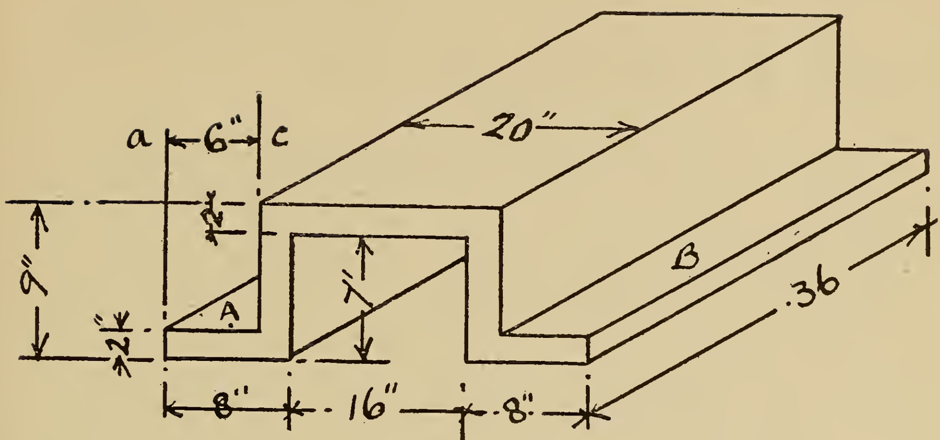


FIG. 63

TABLE OF WEIGHTS

(The approximate weight of a cubic inch of different metals)

1 cubic inch of zinc weighs .252 lb.
1 cubic inch cast iron weighs .26 lb.
1 cubic inch wrought iron weighs .28 lb.
1 cubic inch of steel weighs .288 lb.
1 cubic inch brass weighs .3 lb.
1 cubic inch copper weighs .32 lb.
1 cubic inch lead weighs .41 lb.
1 cubic inch tin weighs .262 lb.

(The approximate weight of a cubic foot of different metals)

1 cubic foot zinc weighs 428 lb. 13 oz.
1 cubic foot cast iron weighs 450 lb. 7 oz.
1 cubic foot wrought iron weighs 483 lb. 6 oz.
1 cubic foot steel weighs 487 lb. 12 oz.
1 cubic foot brass weighs 543 lb. 12 oz.
1 cubic foot copper weighs 547 lb. 4 oz.
1 cubic foot lead weighs 709 lb. 8 oz.
1 cubic foot tin weighs 455 lb. 11 oz.

Weight in pounds of a square foot of different metals, in thickness varying by 1-16 of an inch.

NAME OF METALS

Thickness in Inches.	Wrought Iron.	Cast Iron.	Steel.	Copper.	Zinc.	Brass.	Gun Metal.	Tin.	Lead.
$\frac{1}{16}$	2.3	2.3	2.5	2.9	2.3	2.6	2.7	2.4	3.7
$\frac{1}{8}$	5.0	4.7	5.1	5.8	4.7	5.3	5.5	4.8	7.4
$\frac{3}{16}$	7.5	7.0	7.6	8.7	7.0	8.2	8.2	7.2	11.2
$\frac{1}{4}$	10.0	9.4	10.2	11.6	9.4	11.0	10.9	9.6	14.9
$\frac{5}{16}$	12.5	11.7	12.8	14.5	11.7	13.7	13.7	12.0	18.6
$\frac{3}{8}$	15.0	14.1	15.3	17.2	14.0	16.4	16.4	14.4	22.3
$\frac{7}{16}$	17.5	16.4	17.9	20.0	16.4	19.2	19.1	16.8	26.0
$\frac{1}{2}$	20.0	18.7	20.4	22.9	18.7	21.9	21.9	19.3	29.7
$\frac{9}{16}$	22.5	21.1	25.0	25.7	21.1	24.6	24.6	21.7	33.4
$\frac{5}{8}$	25.0	23.5	25.5	28.6	23.4	27.4	27.3	24.1	37.1
$\frac{11}{16}$	27.5	25.8	28.1	31.4	25.7	30.1	30.0	26.5	40.9
$\frac{3}{4}$	30.0	28.1	30.6	34.3	28.1	32.9	32.8	28.9	44.6
$\frac{13}{16}$	32.5	30.5	33.2	37.2	30.4	35.6	35.0	31.3	48.3
$\frac{7}{8}$	35.0	32.8	35.7	40.0	32.8	38.3	38.2	33.7	52.0
$\frac{15}{16}$	37.5	35.2	38.3	42.9	35.1	41.2	41.0	36.1	55.7
1	40.0	37.5	40.8	45.8	37.5	43.9	43.7	38.5	59.4

NOTE.—The weight per square foot to any gage can easily be obtained from. the above table by multiplying the weight of a square foot of the metal ONE inch thick by the thickness of the gage in inches or parts of an inch.

PART V

THE PRIMARY OR SIMPLE MACHINES

THE MECHANICAL POWERS

Although the combinations of motions are many, they are all related to, and spring from, only two primary principles, namely, the principle of the "Lever" and the principle of the "Inclined Plane."

The lever is the fundamental base of all circular or angular action, that is to say, the lever is the primary element of all action or motion which may be about an axis or center, and the inclined plane is the fundamental base of all rectilinear action, that is to say, the inclined plane is the primary element of all straight-line action or motion.

The primary, or simple machines, sometimes called the mechanical powers, are seven in number, called:

1. The lever.
2. The inclined plane.
3. The cord.
4. The pulley.
5. The wheel and axle.
6. The wedge.
7. The screw.

The first three, that is, the lever, the inclined plane, and the cord, are simple elements, that is, each is an individual element within itself, capable of performing some function. And the other ones are made up of these three; that is, the pulley, the wheel and axle, the wedge, and the screw are combinations of the first three powers, and as the law of each one of the powers is explained in detail, the relation of the "pulley" and the "wheel"

and "axle" to the lever, and the relation of the wedge and screw to the inclined plane, will be clearly seen.

THE SIMPLE MACHINES

The Lever

By lever is meant a stiff bar of any shape, either straight or bent, which is free to turn about a fixed point called the fulcrum (which means a stationary prop or support). When acted upon by two forces in opposite directions, one force acts as a power and the other as a load.

Therefore, in the law of the lever three points must be considered:

First. The fulcrum or point, about which the bar turns.

Second. The point where the power is applied.

Third. The point where the load, resistance, or weight is applied.

Levers are divided into three classes.

In the first class the fulcrum (F) is between the power (P) and the weight (W). (Fig. 64.)

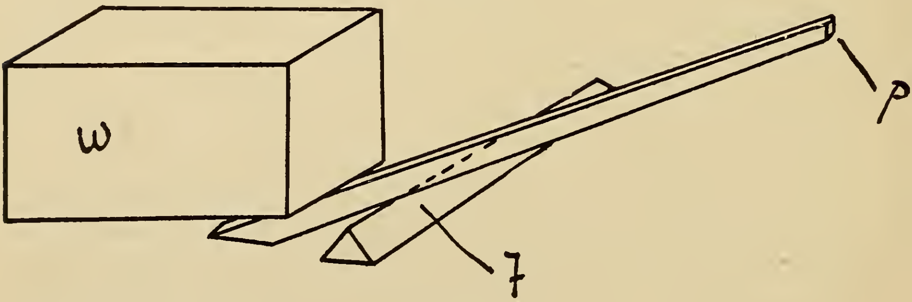


Fig. 64

P = Power.
F = Fulcrum.
W = Weight, in all figures.

In the second class the weight is between the power and the fulcrum. (Fig. 65.)

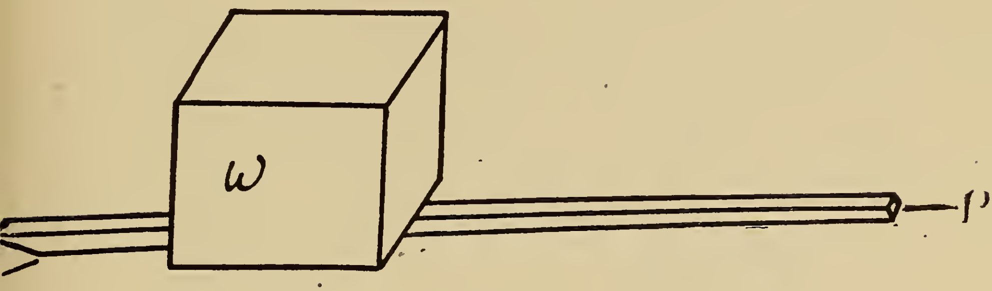


Fig. 65

In the third class the power is between the fulcrum and the weight. (Fig. 66.)

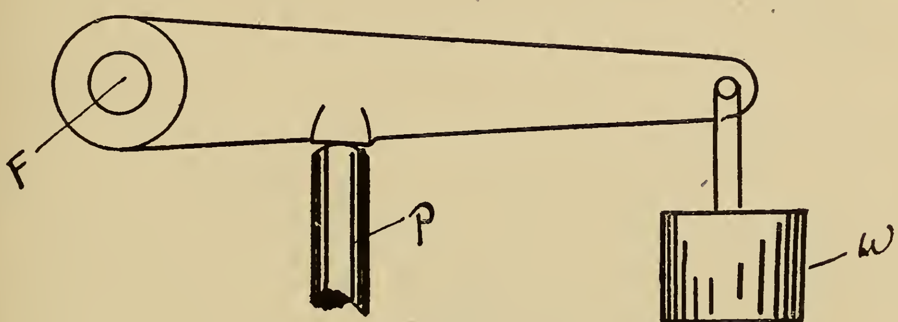


Fig. 66

In all three classes, the law of the lever is the same.

To Find the Power

Rule. Multiply the weight by its distance from the fulcrum and divide by the distance of the power from the fulcrum.

Example. How much power, acting at a point on a lever arm, 16 inches from the fulcrum, will balance a weight of 5 pounds located at a point 8 inches from the fulcrum? (Fig. 67.)

$$\frac{8 \times 5}{16} = \frac{40}{16} = 2\tfrac{1}{2} \text{ lb. pressure.}$$

That is, the pressure exerted by a weight of $2\frac{1}{2}$ pounds 16 inches from the fulcrum, would exactly counterbalance a weight of 5 pounds 8 inches from the fulcrum.

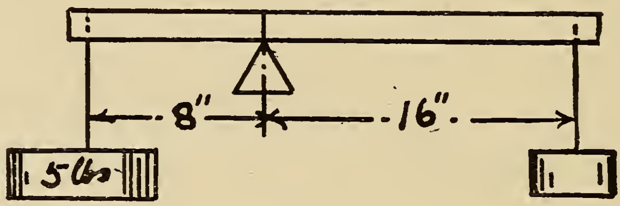


FIG. 67

EXAMPLE. How much power will have to be exerted on a crowbar to raise a stone which weighs 200 pounds, if the crowbar is 5 feet long and the fulcrum is placed at a point 18 inches from the end nearest the weight? (Fig. 68.)

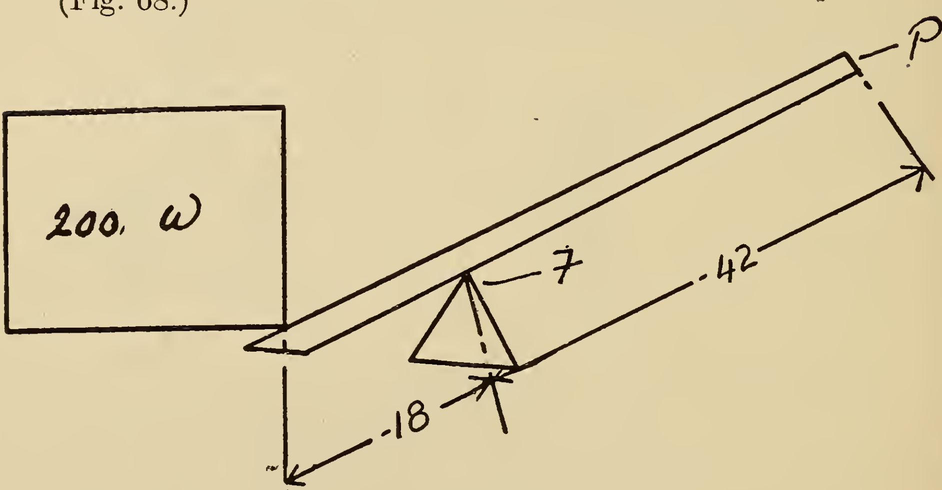


FIG. 68

Here the leverages are 18 and 42.

$$\frac{200 \times 18}{42} = \frac{3600}{42} = 85\tfrac{5}{7} \text{ lb.}$$

That is, a pressure power, or force, of $85\frac{5}{7}$ pounds would with the above lever, counterbalance a weight of 200 pounds.

EXAMPLE. How much power, or force, will be exerted to raise a block of stone which weighs 50 pounds, by a lever of the second order, if the stone is placed 9 inches from the fulcrum and the lever measures 5 feet? (Fig. 69.)

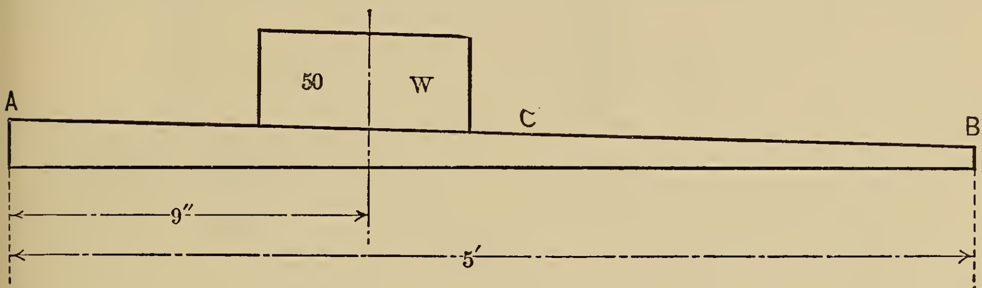


FIG. 69

$$\frac{51 \times 9}{60} = \frac{459}{60} = 7\tfrac{13}{20} \text{ lb.} \quad \textit{Ans.}$$

This answer will appear confusing to some. For such, it will be clearly understood, if they will think of the 50-pound weight as being placed at the point B of the lever, then to raise the weight from that point it would take a force or power equal to 50 pounds. Now remove the weight from the point B to a point C, which is located in the middle of the lever, and a force, or power, of 25 pounds exerted at the point B would be sufficient to raise it. From this the following may be deduced.

The nearer the weight is to the point A, or fulcrum, the less the power required at the point B to raise it.

EXAMPLE. What power, exerted at a point located 3 inches from the fulcrum, will balance a weight of 120 pounds placed 3 feet from the fulcrum?

This is a lever of the third class. (Fig. 70.)

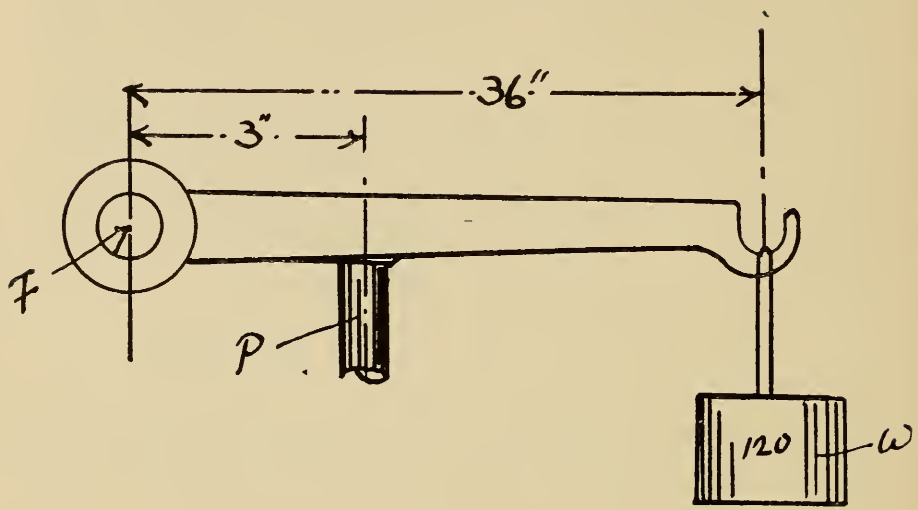


FIG. 70

$$\frac{120 \times 36}{3} = \frac{4320}{3} = 1440 \text{ lb. pressure.}$$

To Find the Weight

RULE. Multiply the power by its distance from the fulcrum and divide by the distance of the weight from the fulcrum.

EXAMPLE. What weight located 36 inches from the fulcrum will be counterbalanced by a force of 50 pounds acting 6 inches from the fulcrum? (Fig. 71.)

$$\frac{6 \times 50}{36} = \frac{300}{36} = 8\tfrac{1}{3} \quad \textit{Ans.}$$

Then a power pressure, or weight of $8\frac{1}{3}$ pounds placed at a distance of 36 inches from the fulcrum will balance a weight of 50 pounds placed 6 inches from the fulcrum.

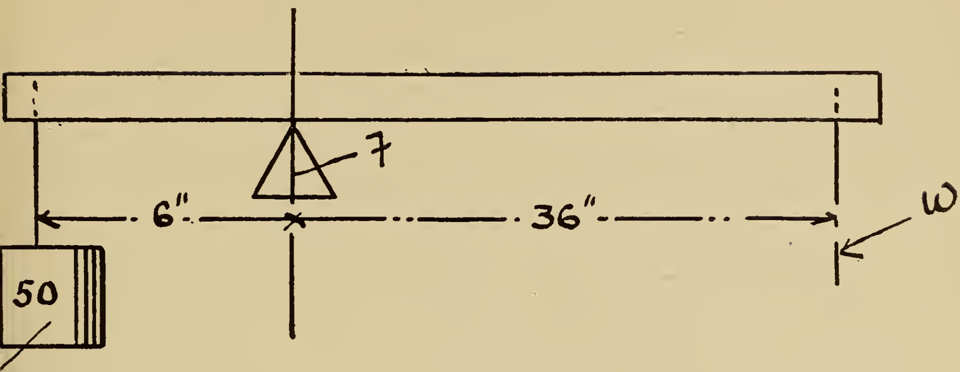


FIG. 71

EXAMPLE. Let A, B, C, be a bent lever with a force equal to 40 pounds applied at A on the long arm, the length A, B, is 16 inches, and the length of the short arm, B, C, is 4 inches. What weight at C can be lifted? (Fig. 72.)

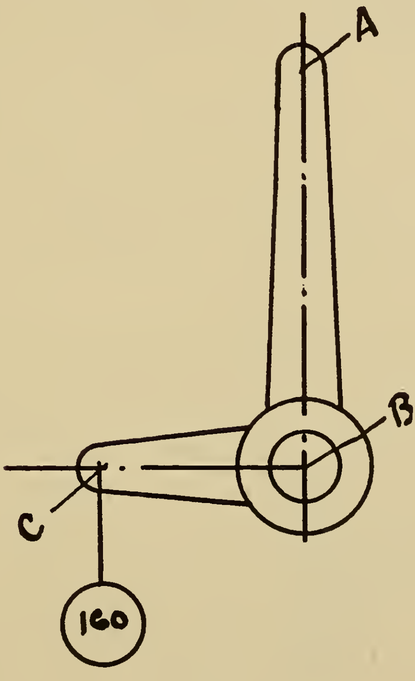


FIG. 72

$$\frac{40 \times 16}{4} = \frac{640}{4} = 160 \text{ lb.} \quad \textit{Ans.}$$

EXAMPLE. Let A, B, C, be a bent lever with a force equal to 80 pounds applied at A on the short arm, the length A, B, is 12 inches, and the length B, C, is 96 inches. What weight at C can be lifted? (Fig. 73.)

$$\frac{80 \times 12}{96} = \frac{960}{96} = 10 \text{ lb.} \quad \textit{Ans.}$$

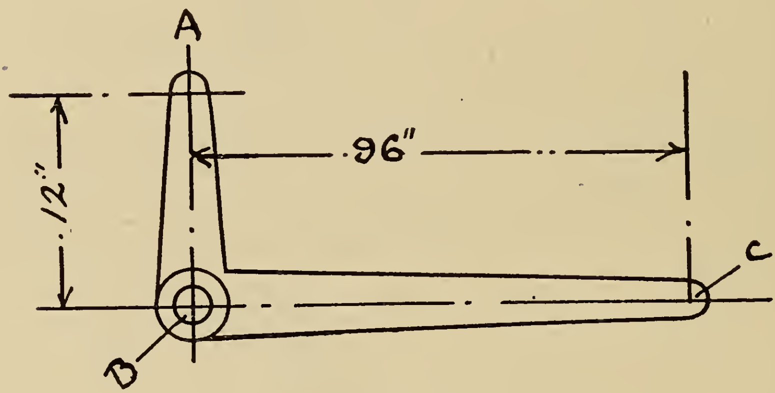


FIG. 73

EXAMPLE. If a force of 112 pounds is applied 12 inches from the fulcrum, what weight at A, which is 36 inches from the fulcrum, can be lifted? (Fig. 74.)

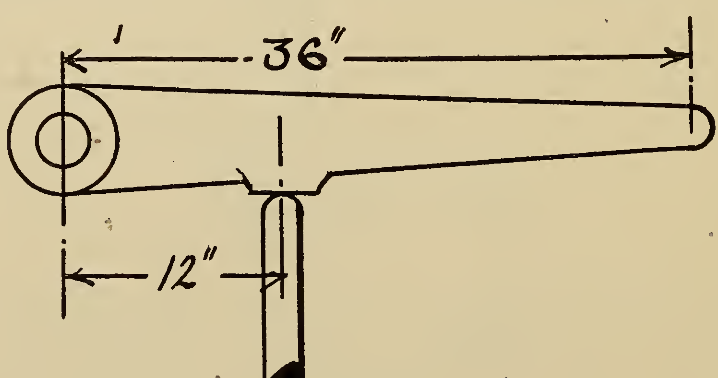


FIG. 74

$$\frac{112 \times 12}{36} = \frac{1344}{36} = 37\tfrac{1}{3} \text{ lb.} \quad \textit{Ans.}$$

To Find the Distance of the Power from the Fulcrum

Rule. Multiply the weight by its distance from the fulcrum and divide by the power.

Example. How far from the fulcrum will a power of 50 pounds have to be placed to raise a weight of 300 pounds, which is 9 inches, from the fulcrum? (Fig. 75.)

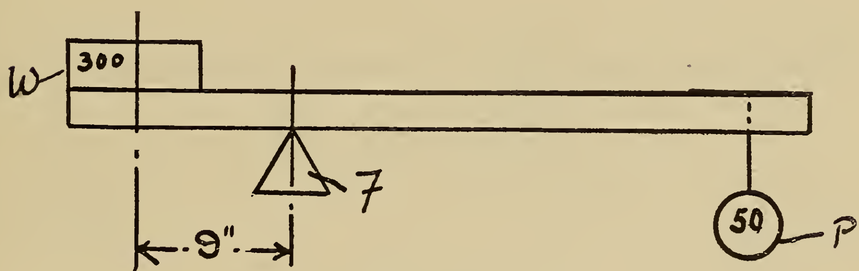


Fig. 75

$$\frac{300 \times 9}{50} = \frac{2700}{50} = 54 \text{ inches.} \quad \textit{Ans.}$$

Example. Let A, B, C, be a bent lever with a power or force equal to 40 pounds applied at A. How long will A, B, have to be to lift a weight of 150 pounds if A, C, equals 7 inches? (Fig. 76.)

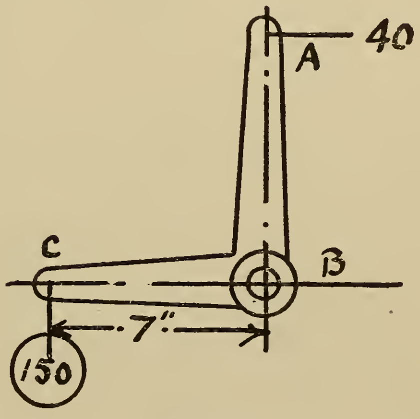


Fig. 76

$$\frac{150 \times 7}{40} = \frac{1050}{40} = 26\tfrac{1}{4} \text{ inches.} \quad \textit{Ans.}$$

To Find the Distance of the Weight from the Fulcrum

Rule. Multiply the power by its distance from the fulcrum and divide by the weight.

Example. How far from the fulcrum will a weight of 500 pounds balance a power of 300 pounds placed 72 inches from the fulcrum? (Fig. 77.)

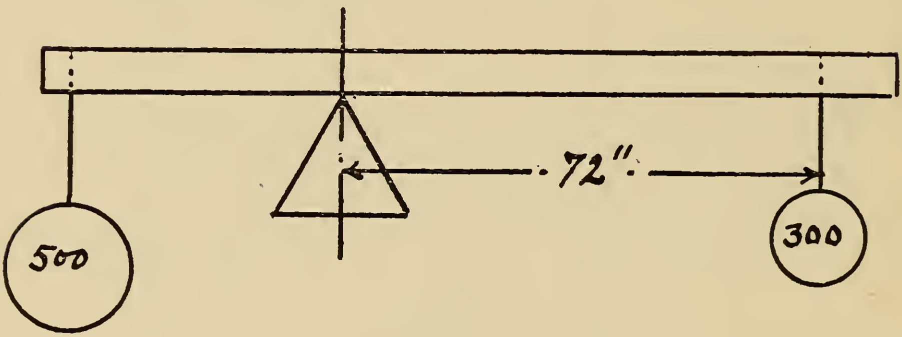


Fig. 77

$$\frac{72 \times 300}{500} = \frac{21600}{500} = 43.2 \text{ inches.} \quad \textit{Ans.}$$

Weights Between Two Supports

If a weight is attached to a beam which rests upon two supports, the beam acts as a lever of the second class, and the part of the whole weight carried by either support may be found by considering one support as the power and the other as the fulcrum. If the weight rests in the middle of the beam it is obvious that each support will carry half the burden. But if, as shown in Fig. 78, the load or weight is placed a distance equal to one

quarter the length of the beam from A, the support A will bear three quarters the weight and the support B one quarter.

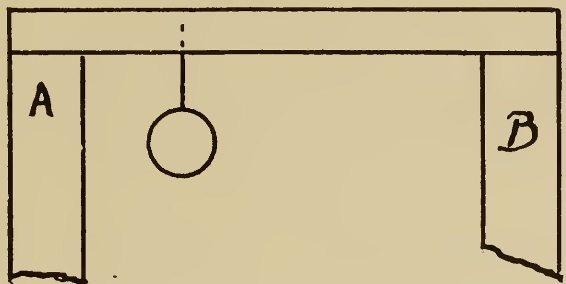


FIG. 78

EXAMPLE. A beam 16 feet long is resting on two supports, A and B, there is a weight of 4 tons hanging 5 feet from A. What share of this weight will be supported by A and B respectively? (Fig. 79.)

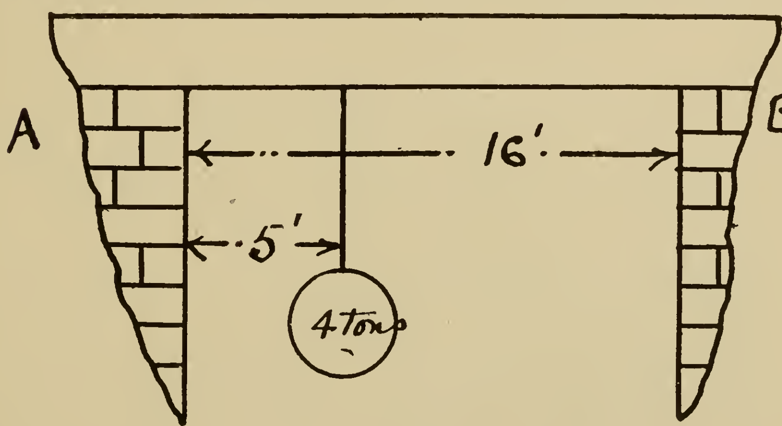


FIG. 79

Support A holds $2\frac{3}{4}$ tons.
Support B holds $1\frac{1}{4}$ tons. *Ans.*

By the principle of the lever, the shorter arm must bear the greater weight and the longer arm the smaller weight.

This fact was clearly demonstrated by Fig. 69.

The following figure will clearly explain the solving of all such problems as the above.

Consider A, B, Fig. 80, a lever of the second class, 16 feet long, with a weight of 4 tons placed 5 feet from the fulcrum. How much power, or what pressure exerted at B, will exactly counterbalance it?

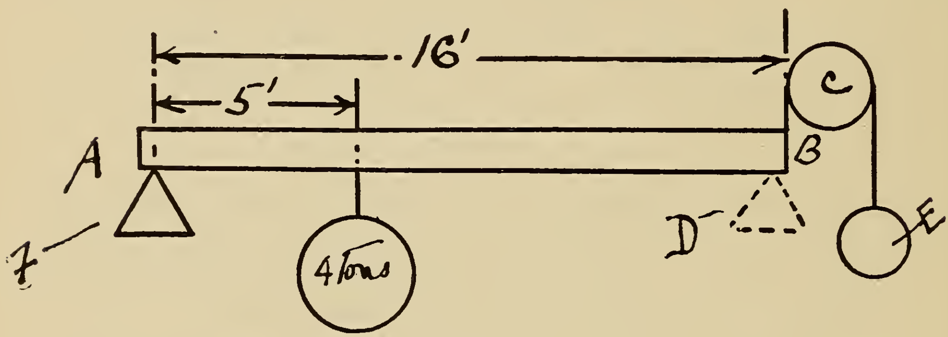


Fig. 80

$$\frac{5 \times 4}{16} = \frac{20}{16} = 1\tfrac{1}{4} \text{ tons.} \quad \textit{Ans.}$$

That is to say, a weight of $1\frac{1}{4}$ tons arranged over a pulley C, as shown in figure, would exactly counterbalance a weight of 4 tons placed as in the above.

Now place a support D under the lever at B, take away weight E letting lever rest on support D, it is obvious then that support D will be resisting a pressure of $1\frac{1}{4}$ tons, or that D will be supporting a weight of $1\frac{1}{4}$ tons.

And as according to the law of the lever the shorter arm (in this case the distance from the fulcrum to weight) bears the greater weight, it is very clearly seen that the share of the whole weight supported at A must be $2\frac{3}{4}$ tons, because $4 - 1\frac{1}{4} = 2\frac{3}{4}$.

Example. A beam 19 feet long and weighing 700 pounds is resting on two supports A and B, there is a

weight of 4 tons hanging 6 feet from A and another weight of 8 tons hanging 6 feet from B. What share of these weights and beam will be supported at A and B? (Fig. 81.)

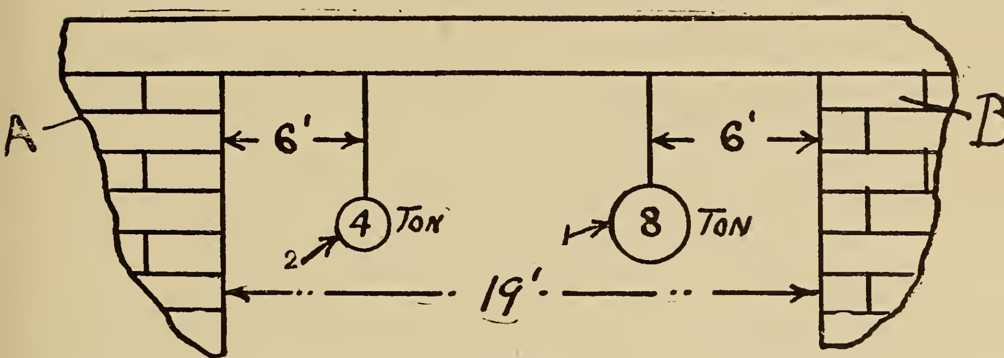


FIG. 81

First find the share each support bears of weight 1.

$\frac{6 \times 8}{19} = \frac{48}{19} = 2.63$ tons = weight of weight 1, supported at A.

Then as A supports 2.63 tons of the weight 1, B must support 5.37 tons of the weight 1.

In the same manner find the share each support bears of weight 2.

$$\frac{6 \times 4}{19} = \frac{24}{19} = 1.27 \text{ tons} = \text{weight of weight 2 at B.}$$

Then as B supports 1.27 tons of weight 2, A must support 2.73 tons of weight 2. And each support bears also half the weight of the beam equals 350 pounds.

Therefore, A's share = 2.63 + 2.73 + 350 =
and B's share = 5.37 + 1.27 + 350 =

Therefore A's share equals 2.63 + 2.73 + 350; A's share in pounds equals 5260 + 5460 + 350 = 11,070 lb., about 5 tons, etc. And B's share equals 5.37 + 1.27 + 350; B's

share in pounds equals 10,740 + 2540 + 350 = 13,630 = 6 tons 10 cwt. 20 lb. = about 6½ tons.

The Compound Lever

By compound lever is meant a combination of levers. Any system of two or more levers acting upon each other is called a compound lever.

By the use of compound levers a very small force applied will sustain a great weight.

And compound levers are used when and where it is inconvenient to use a single lever having a long arm.

Figure 82 shows a system of levers called a compound lever.

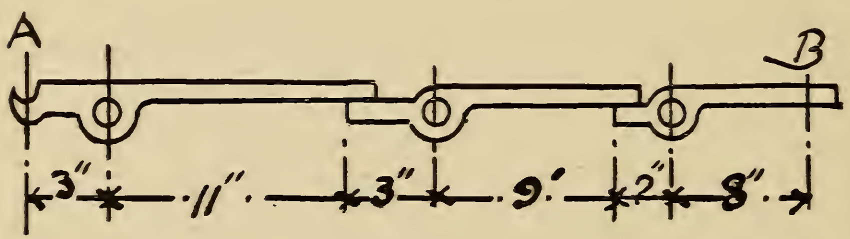


Fig. 82

With such a system of levers as the above, where the short arm of one works on the long arm of the other lever, a very small power applied at B would lift or balance a great weight at A.

To Find the Power

To find the power exerted at B in a combination of levers arranged as in Fig. 82, to balance a weight of 440 pounds suspended from A.

Rule. Multiply the weight by continued product of short arms and divide by continued product of long arms.

Thus in the above Fig. 82, the short arms are 3 inches,

3 inches, and 2 inches, and the long arms are 11 inches, 9 inches, and 8 inches.

Therefore the power required at B to balance a load of 440 pounds at A is

$$\frac{440 \times 3 \times 3 \times 2}{11 \times 9 \times 8} = \frac{7920}{792} = 10. \quad \textit{Ans.}$$

That is, a power of 10 pounds exerted at B will balance a weight of 440 pounds suspended from A, or 10 pounds suspended from B will balance a weight of 440 pounds suspended from A.

To Find the Weight

Rule. Multiply the continued product of the long arms by the power, and divide by the continued product of the short arms.

Example. If there be such a combination of levers as represented in Fig. 82, with long arms of 11 inches, 9 inches, and 13 inches, and short arms of 2 inches, 3 inches, and 2 inches, what weight will be balanced by a power of 10 pounds?

$$\text{Weight} = \frac{10 \times 11 \times 9 \times 13}{2 \times 3 \times 2} = \frac{12870}{12} = 1072.5 \text{ lb.}$$

Then a pressure or power of 10 pounds exerted at A would balance a weight of $1072\frac{1}{2}$ pounds suspended from B.

The Pulley

The pulley is a wheel over which a cord, chain, or band is passed in order to transmit the force applied to the cord, chain, or band in another direction.

The pulley is really a combination of the cord and a wheel, or of a cord and a number of wheels, or of a number of cords and a number of wheels.

The pulley or wheel is introduced only to reduce fric-

tion, and the usefulness of the pulley is dependent wholly upon the cord.

Pulleys are said to be fixed or movable according as their blocks are fixed or movable.

Figure 83 shows a fixed pulley.

In this pulley the block A is fixed or stationary, and the wheel C, D, turns within it.

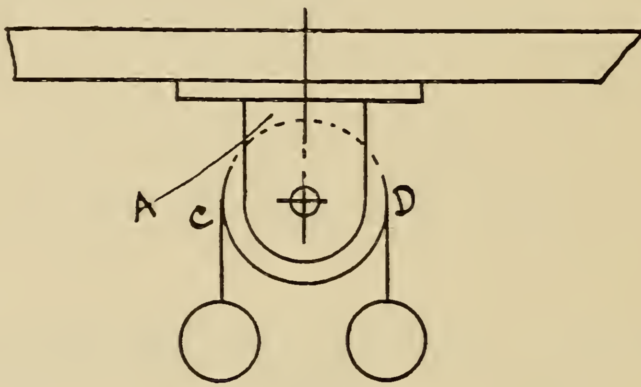


Fig. 83

In Fig. 84 is shown a single movable pulley. In this pulley the block A is movable and the wheel C turns within it.

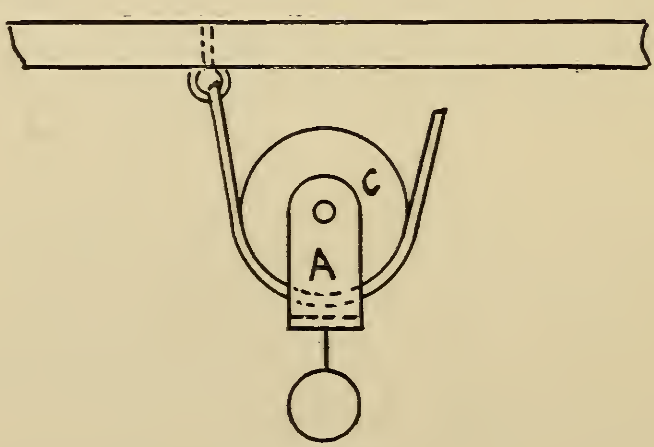


Fig. 84

There is no power or mechanical advantages gained by a single rope acting over one or more single fixed pulleys, but there is often great advantage gained by their use, because, as the force applied to the cord is transmitted in another direction, a fixed pulley or combination of fixed pulleys enables us to change the direction of the force.

Thus it is easier for a man by the use of a fixed pulley to hoist a weight to a loft than it would be for him to carry the weight upwards over a flight of stairs.

Work Done by the Pulley

The pulley may be considered as a continuous series of levers with equal arms on one fulcrum or axis.

Figure 85 represents a fixed pulley which corresponds

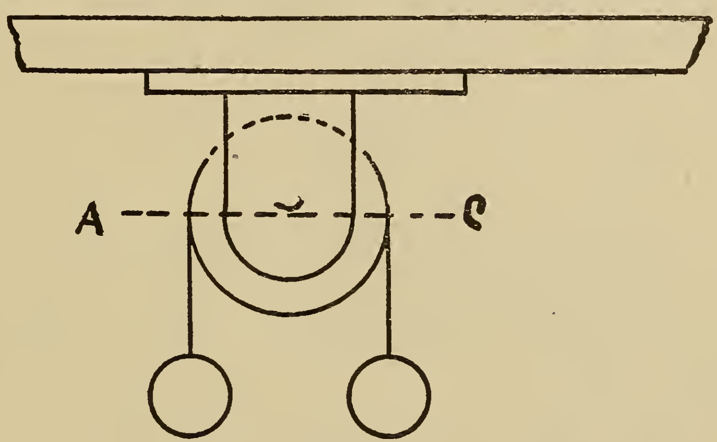


Fig. 85

to a lever of the first class, the center line A, B, C, representing the elements of the lever in which B, the center, may be looked upon as being the fulcrum, and A, B, and A, C, the lever arms.

It is here obvious that the single fixed pulley changes the direction of the force only, without modifying the

intensity of the power. That is, a weight of 100 pounds suspended from A would exactly counterbalance a weight of 100 pounds suspended from C, because A, B, and B, C, are equal, but a force applied to the cord at A, causing it to move in a downward direction, would cause the cord at C to move in an upward direction.

Combination of Pulleys

Movable pulleys are generally used in combination with fixed pulleys. Fig. 86 shows a combination of one fixed pulley with one movable pulley.

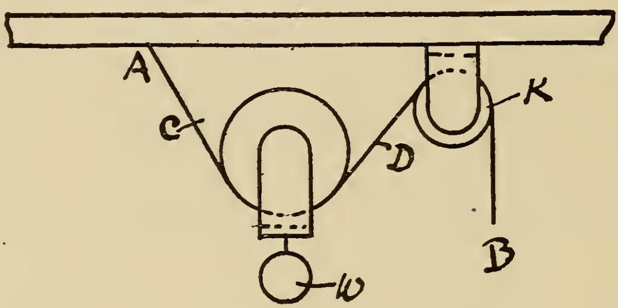


Fig. 86

The figure shows a cord attached to a beam at A, then led around a single movable pulley, and then up over a single fixed pulley; the free end B is where the power is applied, and attached to the movable pulley is a weight = W.

In such an arrangement it is evident that the weight W is supported equally by the two parts C, D, of the cord which passes around the movable pulley, that is to say, the whole weight is supported by the cord and each of the two singles C and D of the cord bears one half the weight; and since no power is gained by the fixed pulley K in this combination it is seen the force at B required to balance the weight W will be half the weight. That is,

50 pounds suspended from B will balance a weight of 100 pounds suspended from the movable pulley, because each part of the cord C and D (called each single of the rope) supports one half the weight. In the combinations of pulleys in common use, several fixed pulleys are contained in one block, and in the other block are an equal number of movable ones.

Figure 87 shows a combination of this kind having two fixed pulleys in the upper block and two movable pulleys in the lower one. In all such combinations of pulleys, one continuous cord passes through the system. The weight here when the lift begins is supported by 4 singles of the rope, and therefore the power required to balance the weight in this combination will be one fourth of the weight. That is, in this system the tension of the weight is equally distributed among the four parts of the cord which sustains the weight, hence a power applied at P will counterbalance four times its weight at W.

From this, then, the following may be deduced:

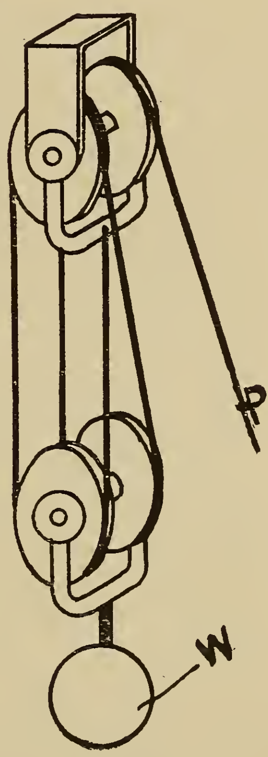


FIG. 87

TO FIND THE POWER

RULE. Divide the weight by the number of singles of rope.

EXAMPLE. A piece of iron weighing 9 tons is lifted by a pair of blocks of two sheaves each, the rope is fastened to the upper block. What power is required to lift it? (Fig. 87.)

$$\frac{9}{4} = 2\tfrac{1}{4} \text{ tons.} \quad \textit{Ans.}$$

Example. A cylinder cover weighing 1100 pounds is lifted by a pair of blocks of two sheaves each, the rope is fastened to the upper block. What power is required to perform the work? (Fig. 87.)

$$\frac{1100}{4} = 275 \text{ lb.} \quad \textit{Ans.}$$

The answers to above examples only tell the amount of power required at B, Fig. 86, and at P, Fig. 87, to evenly balance weights suspended as shown in figures. If it be required to raise the weights, additional power must be applied to overcome friction.

Example. A pair of double blocks are used to lift a ton weight. What power must be applied if 20 per cent be lost by friction?

$$\text{Power required without friction} = \frac{2000}{4} = 500 \text{ lb.}$$

With friction: If the power were 100 pounds (a cwt.), then the weight lifted would be only 80 pounds, as 20 per cent is lost.

Hence, as 80 : 100 :: 500: power required.

$$\begin{array}{rl} & \underline{100} \\ 8.0) & 50000(625. \quad \textit{Ans.} \\ & \underline{48} \\ & \ \ 20 \\ & \ \ \underline{16} \\ & \ \ \ \ 40 \\ & \ \ \ \ \underline{40} \end{array}$$

Example. A pair of double blocks are used to raise a weight of 2 tons. What must be the power applied at

the free end of the rope, if 20 per cent be lost by friction?

Weight in pounds = $2000 \times 2 = 4000$ lb.

Power required without friction, $\frac{4000}{4} = 1000$.

With friction, 80 : 100 :: 1000 : power required.

$$
\begin{array}{l}
\quad\ \ 100 \\
8.0)\overline{100000}(1250. \quad \textit{Ans.} \\
\quad\ \ 8 \\
\quad\ \ \overline{20} \\
\quad\ \ 16 \\
\quad\ \ \overline{\ \ 40} \\
\quad\ \ \ \ 40 \\
\quad\ \ \ \ \overline{\ 0}
\end{array}
$$

The Strength of a Rope

The strength of a rope depends upon its area or circumference; the circumference called the girth being generally used. The rule is that the girth or circumference squared and divided by 24 is equal to the weight that may be lifted expressed as tons. The divisor 24 varies with the quality of the rope.

Example. It will be safe to lift how many tons with a rope whose girth is 14 inches?

$$14^2 \div 24 = 8\tfrac{1}{6} \text{ tons.} \quad \textit{Ans.}$$

Example. What weight may be lifted by a rope $2\frac{1}{2}$ inches in girth? $2\frac{1}{2} = 2.5$.

$$2.5^2 \div 24 = 260 \text{ lb.} \quad \textit{Ans.}$$

Example K. What weight may be safely lifted by a rope whose girth is 3 inches?

$$3^2 \div 24 = \tfrac{3}{8} \text{ of a ton} = 750 \text{ lb.}$$

To Find the Breaking Stress of a Rope

Rule. — Multiply the girth squared by .28, the product is the breaking stress in tons.

Example L. — What is the breaking stress of a rope 3 inches in girth?

$$3^2 \times .28 = 2.52 \text{ tons} = 4500 \text{ lb.}$$

Note that Example K shows that it is only safe for a rope of 3 inches girth to lift 750 pounds, and that Example L shows that a rope whose girth is 3 inches will not break till a weight of 2.52 tons or 4500 pounds be applied.

In practice the working load for round rope should not exceed a seventh of the ultimate strength and for flat rope one ninth. Therefore, if the ultimate strength of a rope whose girth is 3 inches equals 2.52 tons or 4500 pounds it would not be safe to put a working load on that rope exceeding one seventh of 4500 pounds, 642 pounds, although in practice often such a rope carries 700 to 800 pounds load.

Example. — What is the breaking stress of a rope $4\frac{1}{2}$ inches in girth?

$$4.5^2 \times .28 = 7.23 \text{ tons. } \textit{Ans.}$$

The Wheel and Axle

The wheel and axle may be likened to a couple of pulleys of different diameters united on one axis of which the larger is the wheel and the smaller the axle.

As shown in Fig. 88 the combination consists of a wheel, or drum A mounted upon an axle B.

The power is applied at the cord wrapped around the wheel A, and the weight or resistance suspends from a cord wrapped around the axle B.

The wheel and axle is really a lever of the first class and may be treated as such. In which, as shown in

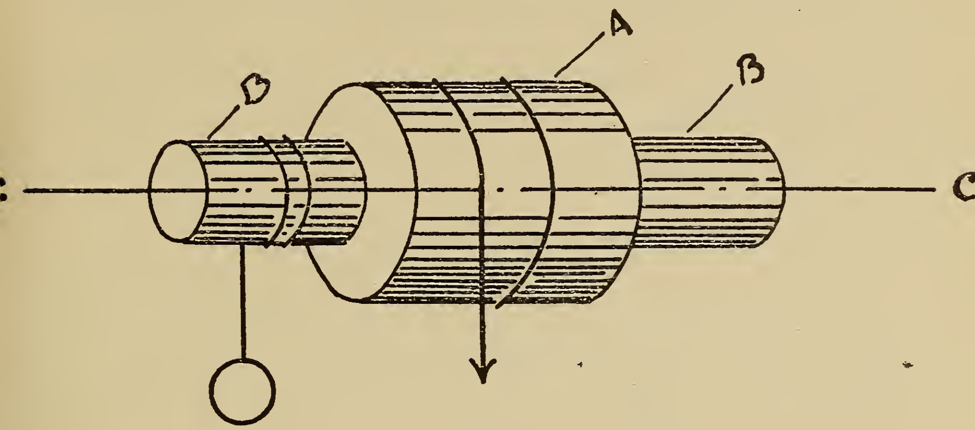


Fig. 88

Fig. 89, the center line A, C, represents the elements of the lever, D being the fulcrum about which the lever turns.

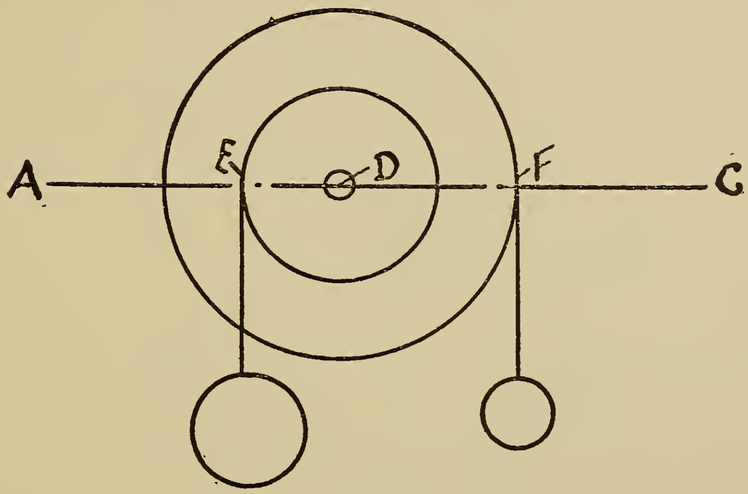


Fig. 89

The radius D, F, of the wheel will be the leverage of the force applied, or power, and the radius E, D, of the axle the leverage of the weight.

From this, then, we may deduce the following rules: To find the power: multiply the weight by the radius of the axle and divide by the radius of the wheel.

EXAMPLE. What power will be required to lift a weight of 300 pounds if the diameter of the drum or wheel is 12 inches and the diameter of the axle 6 inches. (Fig. 90.)

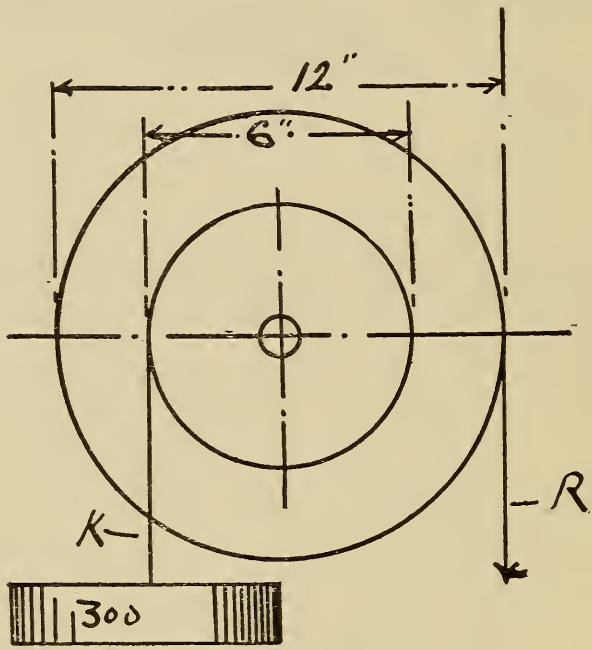


FIG. 90

Radius of axle = 3 inches; radius of wheel = 6 inches.

$$\frac{3 \times 300}{6} = \frac{900}{6} = 150. \quad \textit{Ans.}$$

That is, a pressure of 150 pounds at R will balance a weight of 300 at K.

To find the weight: Multiply the power by the radius of the wheel and divide by the radius of the axle.

Example. What weight will be balanced by a power of 75 pounds if the diameter of the wheel is 10 inches and the diameter of the axle 5 inches? (Fig. 91.)

Radius of axle = 2.5 inches; radius of wheel = 5 inches.

$$\frac{75 \times 5}{2.5} = \frac{375}{2.5} = 150 \text{ lb.}$$

Then a weight of 150 pounds at A will be balanced by a pressure of 75 at B.

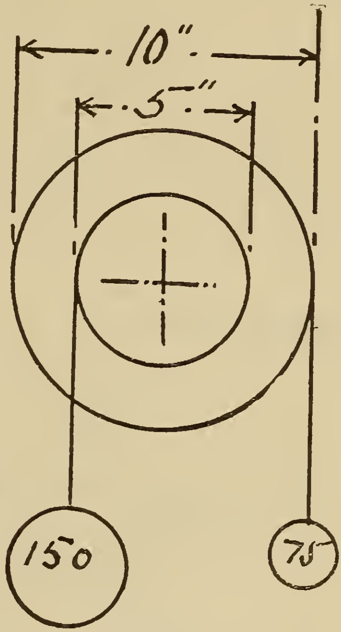


Fig. 91

Example. The diameter of a steering wheel is 4 feet and the barrel is 14 inches diameter. What resistance will be overcome if a man applies a force equal to 200 pounds. (Fig. 92.)

4 feet = 48 inches diameter, or 24 inches radius of wheel; 14 inches diameter = 7 inches radius of axle.

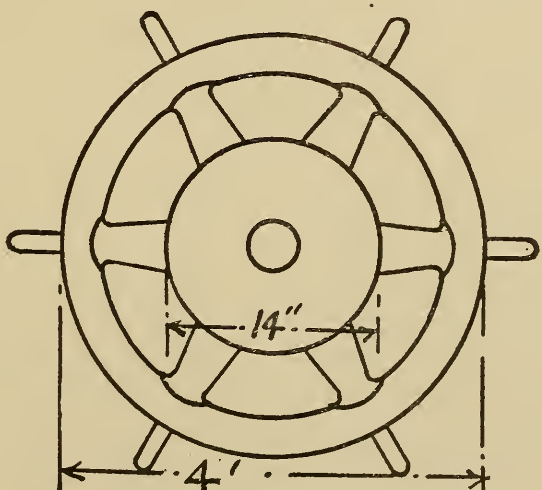


Fig. 92

$$\text{Then } \frac{200 \times 24}{7} = 687 \text{ lb.}$$

The Windlass

The windlass is a combination of the wheel and axle in which a crank answers the purpose of the wheel.

The windlass consists of an axle A, B, and a crank C, D, E, Fig. 93, by means of which the axle A, B, is turned.

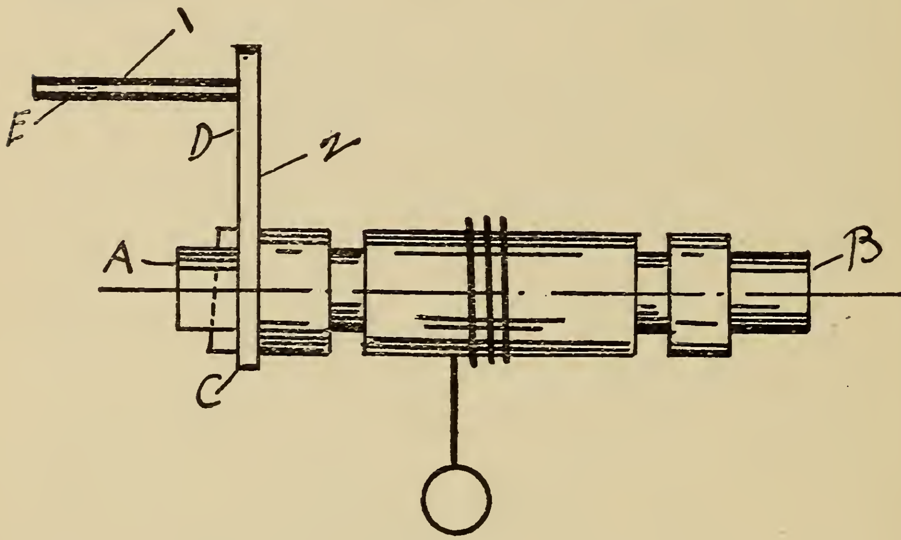


Fig. 93

As shown in figure, the crank is an arm standing perpendicular to the axle.

The part 2 of the crank is called the crank arm, and the part 1 is called the crank handle.

The windlass is used for raising heavy weights and is operated by applying the power to the crank handle 1, the weight to be raised being made fast to the cord, which is fast to and wraps around the axle as same is made to revolve.

EXAMPLE. What weight will be raised by a windlass, if a pressure of 150 pounds be applied to the crank handle? From center of axle to center of crank handle 15″ and axle 10″ diameter.

$$\frac{15 \times 150}{5} = 450 \text{ lb.} \quad \textit{Ans.}$$

In the last example suppose 10 per cent of the force applied be lost through friction and other causes, what would have been the weight lifted?

10 per cent of 450 = 450

$$\begin{array}{r} 10 \\ \hline 45.00 \end{array}$$

$$\text{Then } 450 - 45 = 405 \text{ lb.} \quad \textit{Ans.}$$

In other words, as 10 per cent, that is one tenth is loss, nine tenths must be left.

$$\text{Hence, } \tfrac{9}{10} \text{ of } 450 = 405 \text{ lb.} \quad \textit{Ans.}$$

In the examples given, the diameter of the rope has not been considered because ropes of the sizes required to lift such weights would be too small in diameter to consider. If, however, the rope used is very thick, then the leverage must be measured from the center of the axle to the center of the rope.

EXAMPLE. In a windlass, the center of crank handle is 10 inches from center of axle and from center of axle to center of rope is $6\frac{1}{4}$ inches. What weight will a pressure of 150 pounds raise, 10 per cent being lost in friction?

$$\frac{10 \times 150}{6.25} = \frac{1500}{6.25} = 240 \text{ lb. without loss due to friction.}$$

$$10\% \text{ of } 240 = 24.$$

$$\text{Then } 240 - 24 = 216 \text{ lb.} \quad \textit{Ans.}$$

The Differential Windlass

The differential windlass sometimes called the Chinese wheel and axle, as shown in Fig. 94, differs from the common windlass, Fig. 93, in having an axle formed by two drums A and B of different diameters. A cord is attached to the larger cylinder and several times wrapped around it, then passes under a movable pulley C, and then is wrapped in an opposite direction around the smaller cylinder B.

The power is applied at the crank arm as in the common windlass, but the weight is suspended from the movable pulley C.

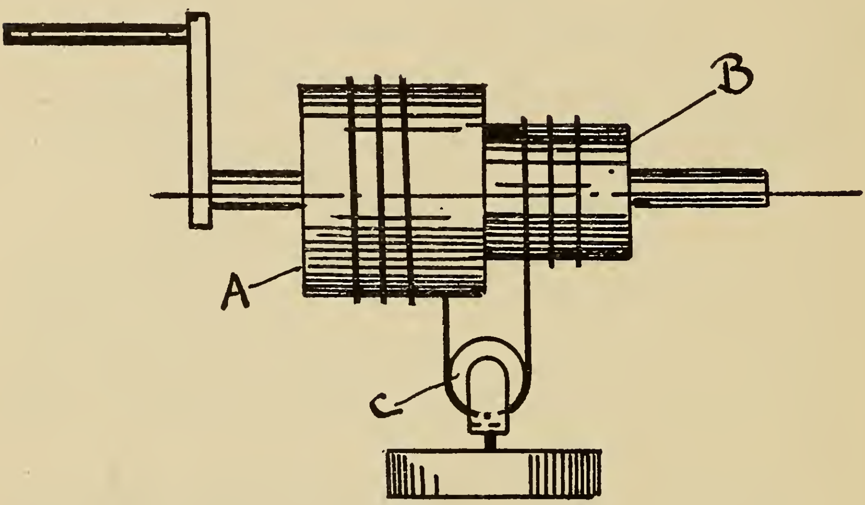


Fig. 94

With this arrangement of windlass, when the handle is turned so as to wind up rope on the cylinder A it is at the same time unwound from the cylinder B, and at each revolution of the crank handle the rope is shortened only by the difference in the circumference of the cylinders. The greater the difference in the circumferences, the quicker the weight will move, and the less the difference

the slower it will move, and by having them nearly equal the weight moves very slowly and great power is gained.

Example. In a differential windlass the diameters of the drums are 1 foot and $\frac{3}{4}$ of a foot, the length of the crank arm is 2 feet 3 inches and the power applied to the crank handle is equal to 90 pounds. What weight will be lifted?

Rule. Multiply the length of crank arm in feet by the power, and divide by half the difference in feet of the the radii of the drums.

Thus 2 feet 3 inches = $2\frac{1}{4}$ feet = 2.25 feet, length of arm in feet.

Then $2.25 \times 90 = 202.50 \div \frac{1}{2}$ difference in feet of radii = *Ans.*

As the diameters of the drums are 1 foot and $\frac{3}{4}$ feet (= 9 inches) the radius of the larger drum will equal 6 inches and the radius of the smaller drum equals $4\frac{1}{2}$ inches.

Then the difference between the radii is $6 - 4.5 = 1.5$ inches difference between radii of drums.

Then $\frac{1}{2}$ of $1.5 = \frac{3}{4} = .75$ of an inch.

Now reduce .75 of an inch, which is $\frac{1}{2}$ the difference of the radii in inches, to the decimal of a foot.

$$\begin{array}{l} \text{Thus } 12).75(.0625 \text{ of a foot.} \\ \quad\quad\quad\;\; \underline{72} \\ \quad\quad\quad\;\;\; 30 \\ \quad\quad\quad\;\;\; \underline{24} \\ \quad\quad\quad\;\;\;\; 60 \\ \quad\quad\quad\;\;\;\; \underline{60} \end{array}$$

$$\text{Then, } \frac{202.5}{.0625} = 3240 \text{ lb. } \quad \textit{Ans.}$$

The Inclined Plane

The inclined plane is a flat surface inclined to the horizon. Any plane which forms with a horizontal plane any angle whatever excepting a right angle may be considered an inclined plane.

In Fig. 95 the line A, then, is an inclined plane because it is a surface inclining to the horizontal line B.

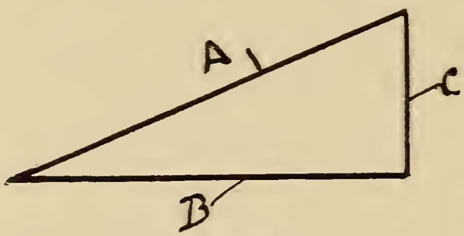


Fig. 95

The inclined plane is used for raising weights, and by referring to Fig. 95 it will be seen that less power would be required to raise a given weight by the use of the sloping path formed by line A than would be required if surface A approached nearer to the perpendicular as shown in Fig. 96.

The less the height of the plane in proportion to its length, or the less the angle of inclination. the greater the mechanical effect; and the greater the height of the plane in proportion to its length the less will be the mechanical effect.

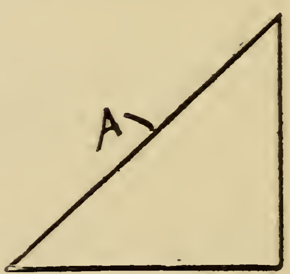


Fig. 96

The following explanation will more clearly explain this:

When a body rests on a horizontal plane. say for example on a table, the action of gravity tending to draw it down is completely counteracted by the resistance of the plane on which it rests and the body remains at rest.

It is not so, however, when a body is placed on an inclined plane. In this case the force of gravity acts upon

the body in two ways: one perpendicular to the plane, which tends to force the weight through it, and the other parallel to the plane, which tends to draw the weight along parallel to it.

The action of the force of gravity in the first place is counteracted by the resistance of the plane, whilst in the second place the body meeting no resistance in a line parallel to the plane it will be forced along in that direction by the force of gravity acting parallel to the plane. And it is evident that the nearer the plane approaches to

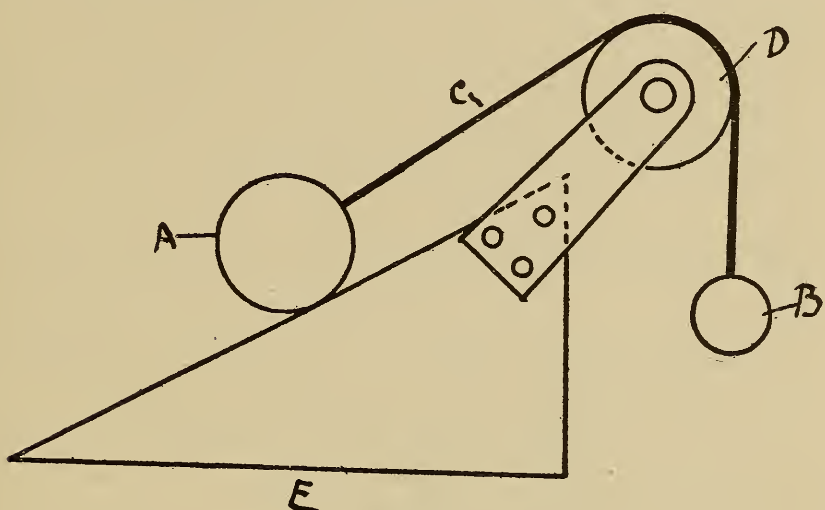


FIG. 97

a horizontal surface, the greater will be the portion of weight supported by the surface. Let the plane be elevated toward the perpendicular and it will support less and less of the weight, till when it reaches an exact perpendicular it will be supporting no part of the weight at all.

Fig. 97 will demonstrate this still more clearly.

In the figure is shown two weights of unequal sizes, A and B, connected by a cord C which passes over a pulley

D. The larger weight A is resting on the inclined surface and is balanced by the smaller weight B. It is evident that the nearer the inclined surface on which the larger weight A is resting approaches the horizontal line E the greater will be the portion of the weight A supported by it, and consequently the less the weight at B will be required to counterbalance A.

Also, the nearer the inclined surface on which A is resting approaches a perpendicular the greater the weight at B will be required to counterbalance A.

From this we learn that the small weight B will counterbalance a weight larger than itself which rests on an inclined plane; and demonstrates the fact that by the use of the inclined plane a given weight can be raised by a power which is less than the weight itself.

Rules for Calculating Work Done by the Inclined Plane

To find the power: Multiply the weight by the height of the plane and divide by the length.

$$P = W \times \frac{\text{Perpendicular height of plane}}{\text{length of plane}}$$

Example. What force is necessary to keep a weight of 100 pounds stationary on an inclined plane whose perpendicular height is 4 feet and length of incline 14 feet, supposing there is no friction?

$$\text{Thus } P = \frac{100 \times 4}{14} = \frac{400}{14} = 28\tfrac{4}{7} \text{ lb.}$$

P = Power or force.

Example. The length of an inclined plane is 19 feet, the perpendicular height 6 feet. What power will be re-

quired to sustain a weight of 250 pounds, supposing there is no friction? (Fig. 98.)

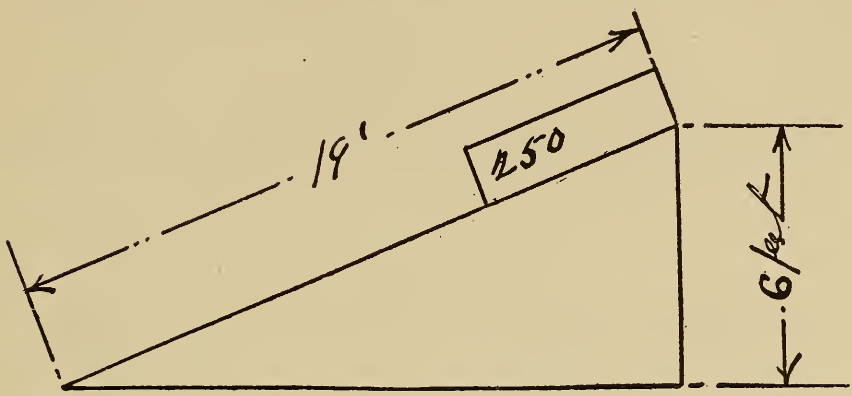


Fig. 98

$$\text{Thus } P = \frac{250 \times 6}{19} = \frac{1500}{19} = 78.9 \text{ lb.} \quad \textit{Ans.}$$

To find the weight: Multiply the power by the length of the plane and divide by the height.

$$W = \frac{P \times L}{H}$$

W = Weight

P = Power

L = Length of plane

H = Height

Example. The length of an inclined plane is 15 feet, the perpendicular height 7 feet. What weight will a power of 78 pounds sustain, supposing there is no friction?

$$\frac{78 \times 15}{7} = 167.1 \text{ lb.} \quad \textit{Ans.}$$

Example. The length of an inclined plane is 15 feet, the perpendicular height 3 feet. What weight will be sustained by a power of 78 pounds?

$$\frac{78 \times 15}{3} = \frac{1170}{3} = 390 \text{ lb.} \quad \textit{Ans.}$$

The Wedge

The form of wedge in general use is the double wedge represented in Fig. 99, which may be likened to a pair of

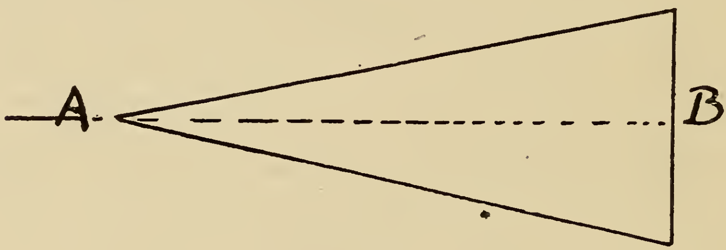


Fig. 99

inclined planes joined together back to back along the dotted line A, B.

There is, however, another form of wedge used called the single wedge, represented in Fig. 100, which may be likened to the inclined plane. Wedges are used where it is

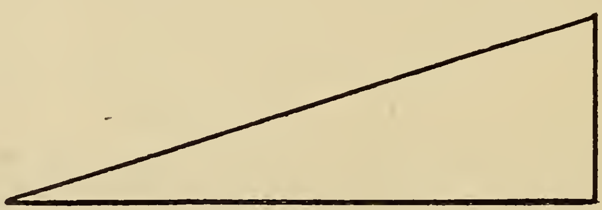


Fig. 100

required to exert a great force in a small space. No accurate estimate can be made of the work done by wedges as they are ordinarily used, but calculations worked out according to the following rules will give an approximate idea of the amount of work which may be performed by them.

To Find the Power

Rule. Multiply weight by thickness of wedge and divide by length of wedge.

Example. A wedge 20 inches long and 3 inches thick is employed to lift a weight of 200 pounds. What power must be exerted? (Fig. 101.)

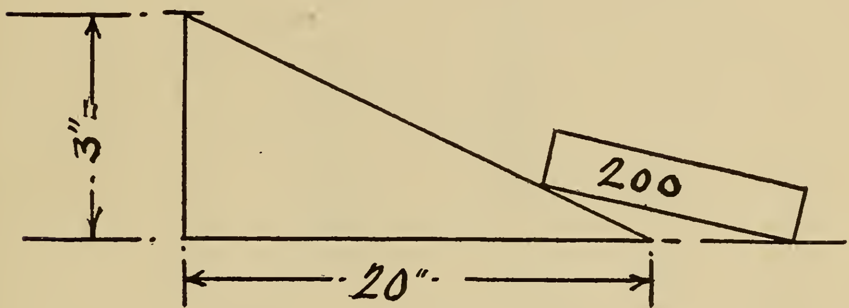


Fig. 101

$$\frac{200 \times 3}{20} = \frac{600}{20} = 30 \text{ lb. pressure}$$

Example. If a wedge 12 inches long and 3 inches thick is employed to raise a weight of 1000 pounds, what pressure must be exerted?

$$P = \frac{1000 \times 3}{12} = \frac{3000}{12} = 250 \text{ lb.} \quad \textit{Ans.}$$

To Find the Weight

Rule. Multiply the power by the length of the wedge and divide by the thickness.

$$\text{Weight} = \frac{P \times L}{T}$$

P = power
L = length
T = thickness
W = weight

Example. If a wedge is 15 inches long and 2 inches thick, what weight will it raise if the power applied is 100 pounds?

$$W = \frac{100 \times 15}{2} = \frac{1500}{2} = 750 \text{ lbs.}$$

Example. If a double wedge 12 inches long 4 inches thick splits a block when it is driven in with a force of 200 pounds, the pressure exerted upon the block by the wedge is how many pounds? (Fig. 102.)

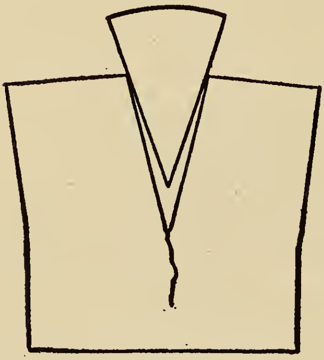


Fig. 102

$$W = \frac{200 \times 12}{4} = \frac{2400}{4} = 600 \text{ lb.}$$

The Screw

The screw is essentially an inclined plane wrapped around a cylinder, as may be seen by taking a triangular piece of paper and winding it around a cylindrical barrel.

Take, for example, the inclined plane A, B, C (Fig. 103), and bend it in circular form resting on its base line

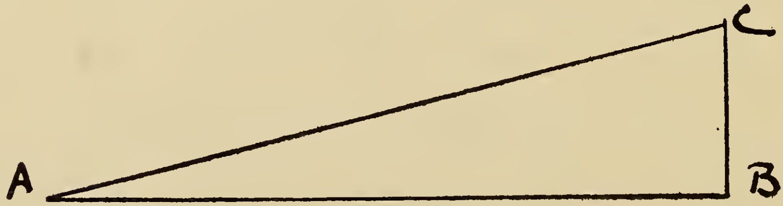


Fig. 103

A, B; by so doing a helical plane 1, 2 will be formed as shown in Fig. 104, which figure shows the inclined plane A, B, C (Fig. 103) curled around the cylinder D.

Here, then, it is seen that as the incline winds around

the cylinder D it assumes a spiral shape more accurately called helical. The screw, then, is really a combination of inclined planes, because it consists of a solid barrel A

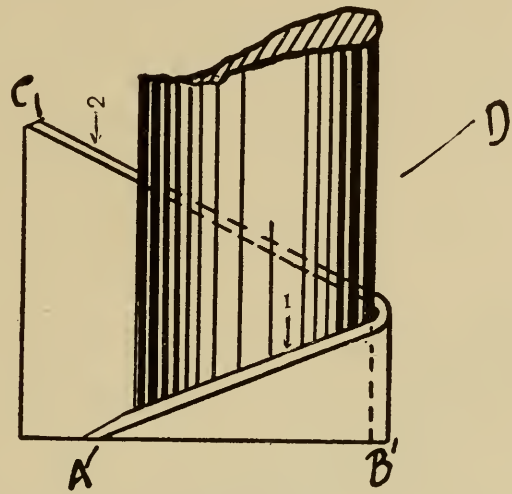


Fig. 104

(Fig. 105) enveloped by a spiral projection called the thread B, which is nothing more than an inclined plane wound around a solid barrel.

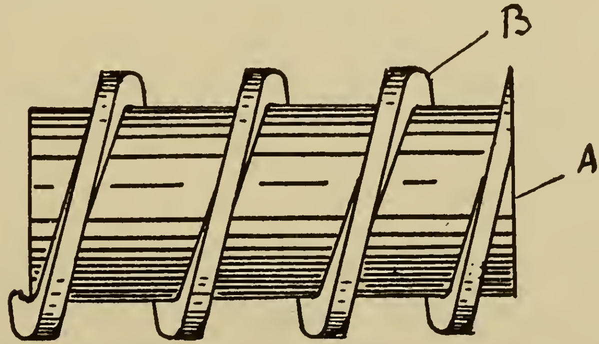


Fig. 105

It is not clearly determined how far the mechanical powers were known to the ancients. Without doubt they

had a knowledge of the lever, the wheel and the axle, and the pulley, and it would seem because of the great engineering feats of construction and building performed by the early Egyptians, that they must have had a knowledge of the principles of the inclined plane; this is only surmised and not an established fact, but it seems very probable, in order to have moved the huge blocks of stone of which the pyramids are built, that they must have had an acquaintance with the inclined plane. Just when the inclined plane was first used in the form of a screw is not known.

The earliest authentic mention we have of the screw being used in mechanics is in the writings of Archimedes. This philosopher and mechanician, about 236 B.C., invented a pumping screw or spiral cylinder for raising water. The device is now known as "Archimedes' screw," and is one of the most ancient contrivances for raising water.

This screw consists of a metallic tube, wound in a spiral form around a solid cylinder or shaft, which is made to revolve by turning a handle. When placed at the proper angle, the water, as the handle is turned, will continue to flow into those parts of the tube that are brought successively below the shaft, till gradually it will be discharged at the top. (Fig. 106.)

Apparently Archimedes did not, however, understand the inclined plane as now used, for he makes no direct mention of it in any of his writings, and there is no positive evidence to show that it was included in the knowledge of mechanics possessed by the Romans.

The inclined plane seems to have been invented by Galileo in the sixteenth century, because several writers of that time allude to the wedge and the screw, showing that a knowledge of these powers formed a part of the

revival of physical science in which Galileo took a most prominent part at that time, even if he did not fully inspire it. However, Stevinnes, a mechanician of Holland, was the first to fully explain in a treatise the theory of the power of the inclined plane and screw.

The first use of the screw was in the screw jack, an appliance used for raising heavy weights.

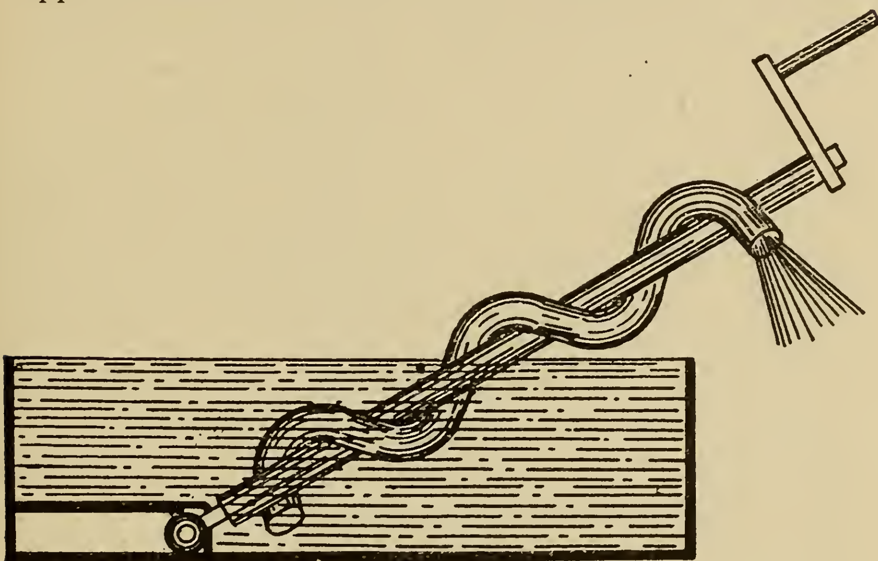


FIG. 106

The various modifications and applications of this power belong to the era of mechanical discovery of the present century.

WORK DONE BY THE SCREW

Screws may be either single-threaded or double-threaded. If we assume that a screw consists of a cylinder with a coil which forms the thread wound around it, we may easily define a double screw as a cylinder with two coils parallel to one another wound around it. The

screw works into a solid, fitted with a thread to receive it, called the nut. The nut may be fixed or movable: when fixed the screw turns within it, and when the nut is movable the screw is fixed, the nut being made to turn upon it.

Motion is imparted to the screw or the nut (whichever the case may be) by means of a lever at the extremity of which the power is applied. The longer the lever and the less the distance between the threads, the greater will be the force exerted at the point of resistance.

Screws are said to be right-handed or left-handed. A right-handed screw is one which, passing through a fixed nut and turned toward the right hand, will advance into the nut. A left-handed screw is one which will, by turning it in a direction toward the left hand, be made advance into a fixed nut.

A screw in one revolution will advance into a fixed nut a distance equal to its pitch, or a distance equal to the distance between the centers of two successive threads. That is to say, if the distance between the centers of two successive threads be $\frac{1}{4}$ inch, the screw during one complete turn will advance into a fixed nut that distance.

The distance between the centers of two successive threads is always called the pitch of the screw.

The following rules give an approximate knowledge of work performed by the screw:

To Find the Power

Rule. Multiply the weight in pounds by the pitch and divide by the circumference of the circle described in inches by the handle employed to turn either the screw or nut one revolution.

Example. If the pitch be $\frac{3}{4}$ inches, and the lever 3

feet long, what power at A will be required to move a weight of 5 tons? (Fig. 107.)

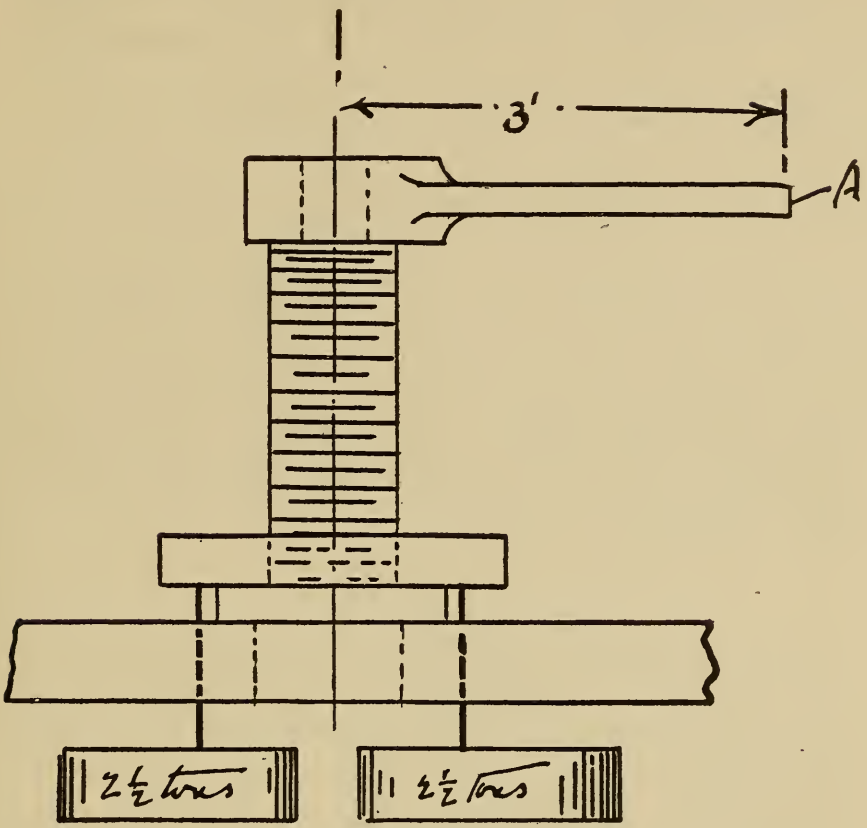


FIG. 107

P = Power

Twice length of lever arm = 6 feet = 72 inches.

Then 72 × 3.1416 = 226.1952 inches circumference of circle described by revolution of lever.

$$5 \text{ tons} = 2000 \times 5 = 10000 \text{ lb.}$$

$$\text{Thus P} = \frac{10000 \times \frac{3}{4}}{226.1972} = 33.1 \text{ lb.}$$

EXAMPLE. If the pitch of a screw be ¼ inch, and the lever be 3 feet long, what force would move 5 tons?

Twice length of lever = 6 feet = 72 inches; $72 \times 3.1416 = 226.1952$ inches circumference of circle described by lever.

Weight in pounds = $2000 \times 5 = 10000$ lb.

$$P = \frac{10000 \times .25}{226.1952} = \frac{2500}{226.1952} = 11 \text{ lbs.}$$

It will be noticed from the above examples, that theoretically there is no limit to the power of the screw, for the distance between the threads may be made as small as you please, and the lever may be made as long as you please; the limits will be mechanical, viz.: the strength necessary to be given to the threads and the space necessary to be given to the lever.

TO FIND THE WEIGHT

RULE. Multiply power by the circumference in inches of the circle described, by the handle or lever employed to either turn the screw or the nut, and divide by the pitch.

EXAMPLE. If the distance between the threads be ¼ inch (= .25), and a force of 100 pounds be applied to the end of a lever 2 feet in length, what weight will be moved by the screw?

Thus: Twice length of lever = 4 feet = 48 inches.

$$W = \frac{100 \text{ lb.} \times 48 \times 3.1416}{.25} = \frac{15079.6800}{.25} = 60318 \text{ lb.}$$

The rule mostly used in practice for determining the weight that can be lifted by a screw, or the tension that can be given a bolt or stud by using a wrench to the nut,

is the distance moved by the power or the hand in making one complete revolution of the wrench, divided by the pitch of the screw and the quotient multiplied by the power applied.

From this deduct 70 to 75 per cent for friction.

All machines, no matter how complicated or what the work is they perform, are combinations of these simple mechanical devices, or primary machines, arranged together and combined so as to give such direction and velocity to the motion that the required work is performed.

PART VI

STRENGTH OF MATERIALS AND QUESTIONS RELATING TO STRESS

STRENGTH OF MATERIALS AND QUESTIONS RELATING TO STRESS

The mechanic, to work intelligently, should be acquainted with the strength of the different materials used in construction. He should also be familiar with the strains, due to the various forces, any of the great variety of materials used will stand before final rupture. And it is therefore necessary that he have a knowledge of those laws which govern the rules for calculating the extent of the strain due to the various forces to be dealt with, and know what to allow as a safe margin of resistance to carry all such forces, and thereby make the required provisions for the strength of parts.

The external forces applied to materials tending to cause their rupture or alteration of form are called stresses. These are five in number, called:

1. Tensial stress.
2. Compressive stress.
3. Transverse stress.
4. Torsional stress.
5. Shearing stress.

A force applied in the line of fiber having a tendency to lengthen the body is called the tensial or breaking stress.

As shown in Fig. 108, the beam A has a tendency to lengthen because of the force exerted upon it by the weight B, and the resistance of A due to the load B to alter its form is the stress, — in this case the tensial stress.

A force which pushes the parts together, tending to shorten or crush the body, is called the compressive stress.

As shown in Fig. 109 the weight A exerts a stress, called compressive stress, upon the column B, tending to crush it.

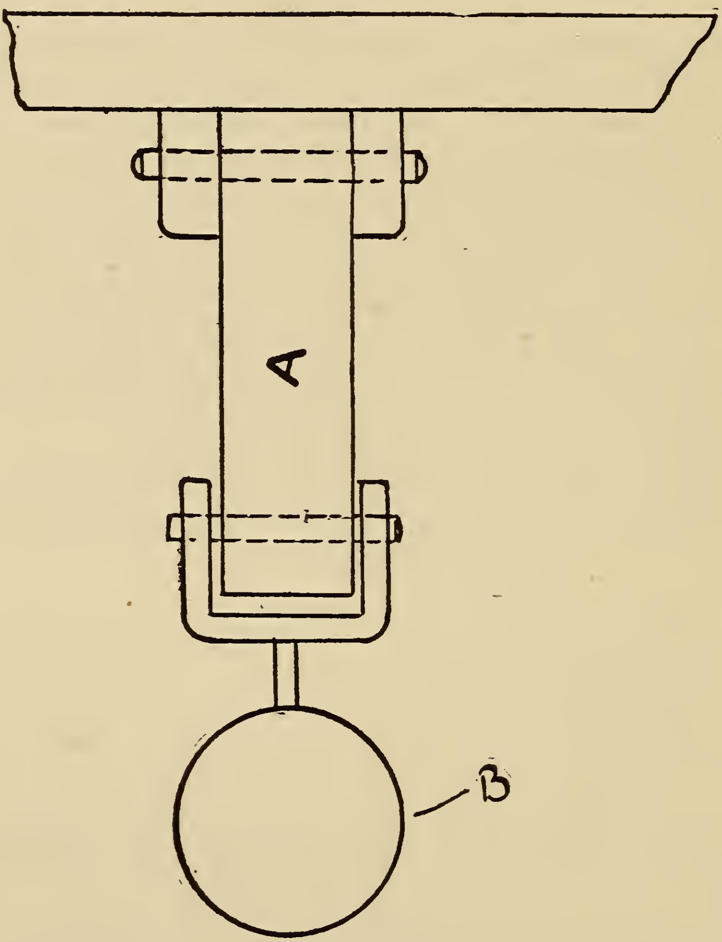


Fig. 108

A force applied to a body in such manner as to cause it to twist is called the torsional stress. As shown in Fig. 110, by applying a power to the lever A in such manner

that it would cause the beam B, which is anchored at C, to twist.

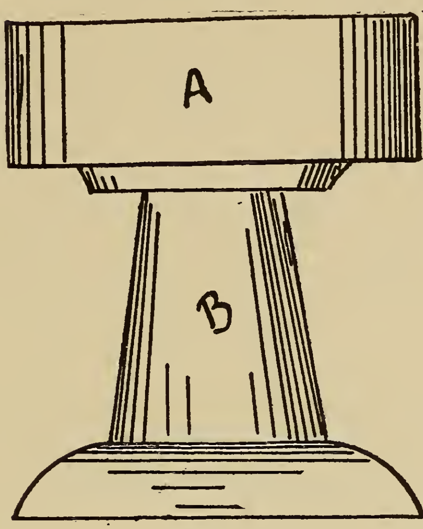


FIG. 109

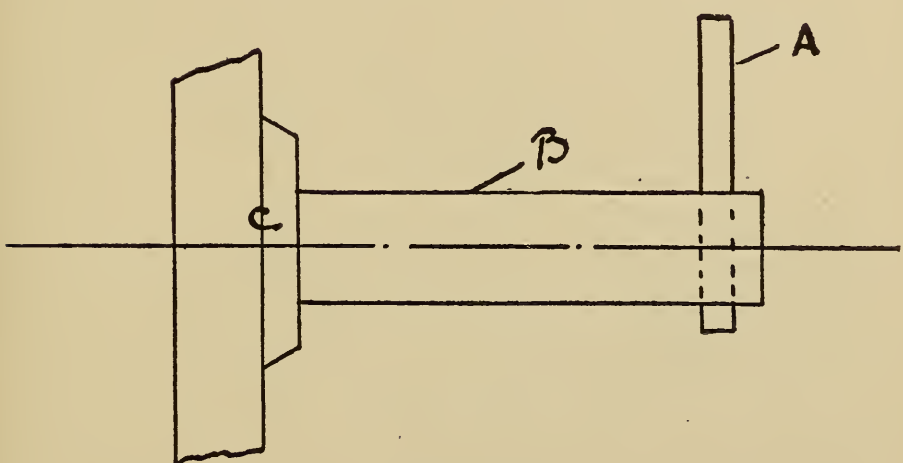


FIG. 110

If a beam is resting on two supports and a weight is placed on the beam between the supports, it is called a transverse stress. (Fig. 111.)

If the beam be fixed at one end and loaded at the other, the stress is a bending stress. (Fig. 112.)

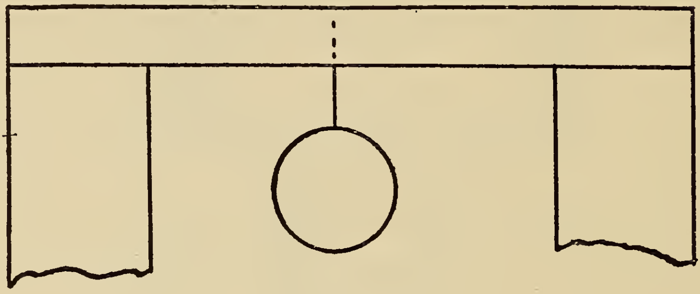


FIG. 111

Lastly, if the stress is such that it acts in a way that it is trying to cut through a body it is called a shearing stress. As shown in Fig. 113, where the cutters A, B, are cutting through the bar C.

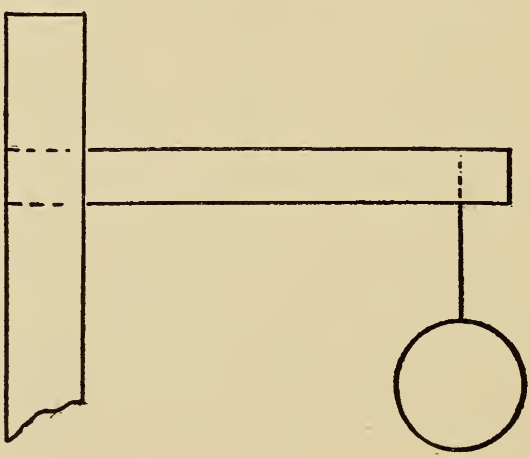


FIG. 112

The immediate result of stress is strain.

Every load which acts on a structure produces a change of form, which is called the strain due to the load. The strain may be either a vanishing or elastic change of form; that is, one which disappears when the load is re-

moved, or it may be a permanent change or set, which remains after the load is removed. Strain, then, is the alteration in shape as the result of stress.

And in designing structures, care must be taken that all parts will have the required strength, so that under the greatest straining action there will be no sensible permanent change in form.

The stress required to strain, change the form of or rupture the various materials in use is usually determined by an apparatus called the Testing Machine, of

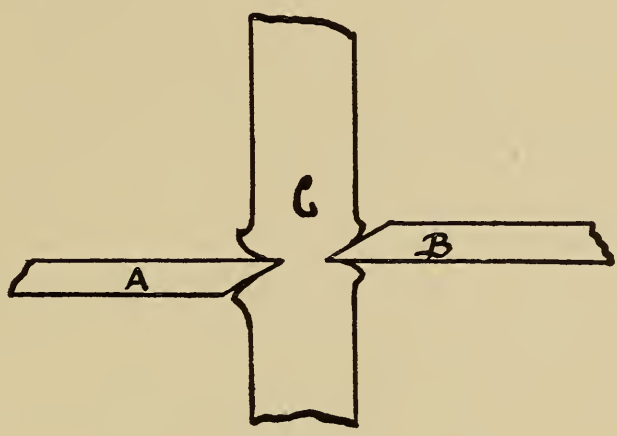


FIG. 113

which there are many different forms, and it may be here pointed out that the differently constructed machines of this class give widely different results, there being a great variation in the data indicated by them representing the standard resistances of the various materials tested.

Therefore, the careful mechanic, rather than depend upon the data given by the different authorities as being correct in representing the strength of the different materials, is obliged to himself test and determine the strength of the materials he proposes to use, and will

regard given data rather as approximate and subject to change than as precedents to be adopted and blindly followed.

It will be the object of this chapter to explain the rules for determining the strain of the approximate stresses due to the action of the different loads, to show by tables and otherwise the approximate strength of the various materials used, and how to make comparative safe provision for sustaining all those forces which enter as factors in construction of every nature.

As cast iron, wrought iron, steel and wood, are the materials mostly used in machine construction, special note had better be made of their various strengths, so that intelligent judgment may be used when these materials are employed to construct the parts of such sizes that they will safely stand the stresses due to the action of the different loads, and thereby prevent straining and rupture.

The stresses to which constructions and parts of constructions are mainly subjected to are the Tensial, Compressive, and Shearing stresses.

Stress is usually measured in pounds per square inch of sectional area. That is, the ultimate strength of materials is usually determined by the number of pounds a square inch of sectional area will undergo before final rupture.

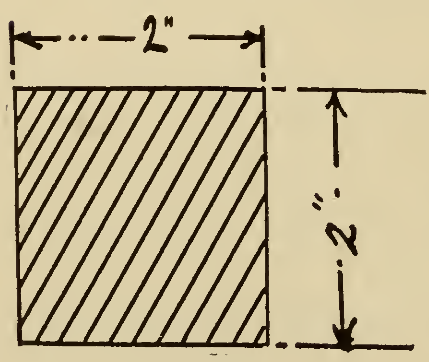


Fig. 113

For instance, if a wrought-iron bar is 2 inches by 2 inches in section. (Fig. 113.) Thus the whole area of section is 4 square inches, and it is obvious that if the ultimate tensial strength of wrought

iron, for instance, is 52,000 pounds per square inch of section, a bar of wrought iron whose sectional area is 4 square inches would be caused to break by a power of $52,000 \times 4 = 208,000$ pounds.

The following tables are approximate of the ultimate strength and elastic strength of different materials commonly used.

Ultimate Strength

By ultimate strength is meant the greatest possible load any piece of material will carry before fracture is produced. In other words, the smallest load which will cause the rupture of a piece of material is called the ultimate strength of that piece; that is, the stress in pounds per square inch which the piece can sustain just before rupture takes place.

Elastic Strength

All materials are more or less elastic and will undergo, when put under great stress, change of form which may be vanishing or permanent as before stated. When the load is such that it has a permanent influence upon the piece and sets it so that it will not return to its original form when the load is removed, the limit of elasticity of the material has been reached (which is the elastic strength), and beyond this limit the strain increases faster than the stress until rupture is produced.

TABLES

TABLE NO. 1

ULTIMATE AND ELASTIC STRENGTH OF MATERIALS IN POUNDS PER SQUARE INCH

NAME OF MATERIALS	ULTIMATE OR BREAKING STRENGTH			ELASTIC STRENGTH		
	Tension.	Compression	Shearing	Tension	Compression	Shearing
Cast Iron......	10.800 to 67.000	90.000	20.000	10.500	21.000	7.900
Wrought Iron..	52.000 to 67.000	52.000	52.000	24.000	24.000	20.000
Soft Steel Unhardened....	60.000 to 100.000	150.000	70.000	35.000	35.000	26.000
Soft Steel hardened........	120.000	120.000	120.000	70.500	70.500	53.000
Cast Steel Untempered....	84.000 to 150.000	84.000 to 150.000	84.000 to 150.000	80.000	80.000	74.000
Cast Steel Tempered.......	100.000	150.000	70.000	84.000	90.000	145.000
Copper........	33.000	58.000	58.000	4.300	3.900	2.900
Brass.........	17.500	10.500	10.500	6.950	6.950	5.200
Gun Metal.....	23.000 to 52.000	23.000 to 52.000	23.000 to 52.000	6.200	6.200	4.150
Phosphor Bronze......	58.000	58.000	58.000	19.700	19.700	14.500

TABLE NO. 2

Table Showing Safe Working Stress in Pounds per Square Inch

ORDINARY WORKING STRESS

NAME OF MATERIALS	SAFE LIMITS IN POUNDS PER SQUARE INCH			THEORETICAL LIMIT OF STRESS		
	Tension	Compression	Shearing	Tension	Compression	Tension Compression
Cast Iron......	3.600	10.400	2.700	5.250	28.500	3.000
Wrought Iron..	10.400	10.400	7.800	17.280	15.000	9.000
Soft Steel Untempered....	17.700	17.700	13.000	24.000	24.000	13.000
Cast Steel Untempered....	36.000	36.000	20.000	52.000	52.000	36.000
Copper........	3.600	3.120	2.300	9.900	17.400	5.500
Brass..........	3.600	3.600	2.700	5.250	3.150	3.000
Gun Metal.....	3.120	3.120	2.400	10.800	10.800	6.000
Phosphor Bronze......	9.870	9.870	7.380	17.400	17.400	9.700

As shown by foregoing tables, 1 and 2, there is a great margin of difference between the ultimate strength and the safe working limit allowed for the load or weight that the various metals will safely carry before straining.

This allowance is made because it is impossible to determine all the forces which produce straining action; therefore, to insure the safety of a structure, we have to make all parts sufficiently strong to support, not only the aggregate amount of straining action due to the forces which are taken into consideration, but also to take care of all unforeseen contingencies due to neglected causes of straining action.

Hence it is necessary that the mechanic be sufficiently informed so that he be able to determine the approximate

stress on a structure, and also be able to determine the necessary strength of the different parts to prevent strain and thereby insure absolute safety. And although by practical experience and familiarity he perhaps gains the best knowledge of the intensity of straining actions due to the different forces, it is customary in practice, when determining the straining actions on a structure, to be more or less guided by various factors of safety.

As just stated, it is impossible to take into consideration all the forces which produce a straining effect upon a structure. However, by multiplying those forces which are known to exist by a factor of safety, a rough and comparatively safe allowance is made for the straining action which is exerted by the unseen forces. And in this way is obtained the approximate stress on the structure due to all causes.

And the sizes and strength of the various materials to be used to carry those various stresses may be determined accordingly.

Following is a table of factors of safety, which are generally adopted in practice for various materials, under dead and varying or live load, and for machines subjected to sudden and frequent strains of short duration, known as shocks.

FACTORS OF SAFETY

Name of Materials	Dead Load	Live Load	Materials Subject to Shocks
Cast Iron	6	10–15	15–20
Wrought Iron	4	6	12
Steel	4	7	15
Copper	5	8–10	10–15
Timber..................	8	10	15
Masonry and Brickwork...	15	25	30

It will be noticed that the factor of safety is less for dead loads than for live or varying loads, and greatest when the structure is subjected to shock.

From which we learn that the stress due to the different loads varies; therefore the nature of the load to be carried must be carefully considered and provisions accordingly made to carry them.

It being impossible to correctly determine the intensity of a load all the parts must be made to resist a much greater load than will be brought to bear on them at any time; therefore the expected load is multiplied by one of the various factors of safety. And this factor of safety varies according to the nature of the load, and consequently for the same materials under the influence of different loads, a greater or less factor of safety must be used.

Tensial Stress

If a bar of iron 1 inch square is torn asunder by a stress of 22 tons, what will be required to break a bar $3\frac{3}{4}''$ square? That is, if a square bar whose sides measure $1''$ is torn asunder by a stress of 22 tons, what will be required to break a square bar whose sides measure $3\frac{3}{4}''$?

```
  3.75
  3.75
  ----
  1875
 2625
1125
-------
14.0625 sq. inches in section of bar.
 44000
-------
562500
562500
-----------
618750.0000 lbs. to break the bar. Ans.
```

```
 2000 = 1 ton.
   22
 ----
 4000
4000
-----
44000 stress in pounds required to break bar 1 inch square.
```

Example. If a bar of cast iron 2 inches square is torn

asunder by a stress of 100,000 pounds, what will be required to break a bar of 3½ inches square?

$$\begin{array}{r@{\ }l}
3.5 & \\
\underline{3.5} & \\
175 & \\
\underline{105} & \\
12.25 & \text{sq. inches in section of bar to be broken.}
\end{array}$$

$$\begin{array}{r@{\ }l}
2 & \\
\underline{2} & \\
4 & \text{sq. inches in section of bar which is broken.}
\end{array}$$

Then if a force of 100,000 pounds is required to break a bar of cast iron of 4 square inches sectional area, how much force will be required to break a cast-iron bar of 12.25 square inches sectional area more?

Thus, 4 : 12.25 :: 100,000: *Ans.*

$$\begin{array}{r}
12.25 \\
\hline
500000 \\
200000 \\
200000 \\
100000 \\
\hline
4)1225000.00 \\
\hline
306250 \text{ lb. to break the bar.} \quad \textit{Ans.}
\end{array}$$

EXAMPLE. If a bar of wrought iron 2 inches in diameter is torn asunder by a weight of 70 tons, what is its breaking stress?

It will be remembered that stress is measured in pounds per square inch of section; and that breaking stress means the stress in pounds per square inch of section required to break any material.

Hence, the question of the above example is to determine the stress in pounds required to rupture a square inch of (in this instance) wrought iron.

Thus $\begin{array}{r} 2 \\ \underline{2} \\ 4 \end{array}$ = square of diameter of bar.

Then, $\begin{array}{r} .7854 \\ \underline{4} \\ 3.1416 \end{array}$ sq. inches in section of bar.

Then if 70 tons is the breaking stress of 3.1416 square inches, what is the breaking stress of 1 square inch?

Thus, 3.1416 : 1 :: 70: *Ans.*

$$\begin{array}{r} 1 \\ 3.1416)70.0000(22 \text{ tons. } \textit{Ans.} \\ \underline{62832} \\ 71600 \\ \underline{62832} \end{array}$$

That is, each square inch of section will stand before breaking a force of 22 tons, or $70 \div (.7854 \times 2^2) = 22.28$ tons per square inch of section. *Ans.*

Example. A piece of plate 9 inches long, 4 inches wide, and $\frac{3}{4}$ inches thick is tested in line of its length and breaks at 72 tons. What is its breaking stress?

Here the section is $4 \times \frac{3}{4} = 3$ square inches.

And the breaking stress = 72 tons $\div$ 3 = 24 tons per square inch of its section. *Ans.*

Compressive Stress

Example. If a solid casting 4 inches diameter is crushed by a weight of 450 tons, what is the crushing strength of this specimen of cast iron?

Thus:

Area of section $= .7854 \times 4^2 = 12.5664$ square inches.

Stress $= 450 \div 12.5664 = 35$ tons.

35 tons per square inch of its section. *Ans.*

EXAMPLE. If a cast-iron column 5 inches by 5 inches holds up a weight of 25 tons, what is the stress in pounds per square inch on the column?

$$\begin{array}{r} 5 \\ \underline{5} \\ 25 \end{array}$$ square inches in section of column.

$$\begin{array}{r} 2000 \\ \underline{25} \\ 10000 \\ \underline{4000} \\ 50000 \end{array}$$

$2000 = 1$ ton

$50000 =$ weight in pounds supported by the column.

Then stress in pounds per square inch of sectional area $= 50000 \div 25 = 2000$ lb. *Ans.*

EXAMPLE. If four solid cast-iron columns, each 4 inches square, hold up a cistern weighing 46 tons, whose inside dimensions are 12 feet long, 8 feet wide, and 6 feet deep, what is the stress per square inch on these columns when the cistern is one half full of water? (Fig. 114.)

First find weight of water in cistern when full, which divide by 2 to obtain weight in pounds when half full. Add to this the weight of cistern when empty. Divide the sum obtained by the total sectional area of the colums (4 of them), and the quotient 1562 is the required answer.

Cubic contents of cistern when full of water $= 12 \times 8 \times 6 = 576$ cubic feet.

1 cubic foot of water weighs 62.5 lb.

Weight of water in cistern $= 576 \times 62.5 \div 2 = 18{,}000$ lb.

Total weight on columns in pounds = 92,000 (46 tons) and 18,000 = 100,000 lb.

Total sectional area of columns = $4 \times 4 \times 4 = 64$ square inches.

Stress per square inch = $100,000 \div 64 = 1562$ lb. *Ans.*

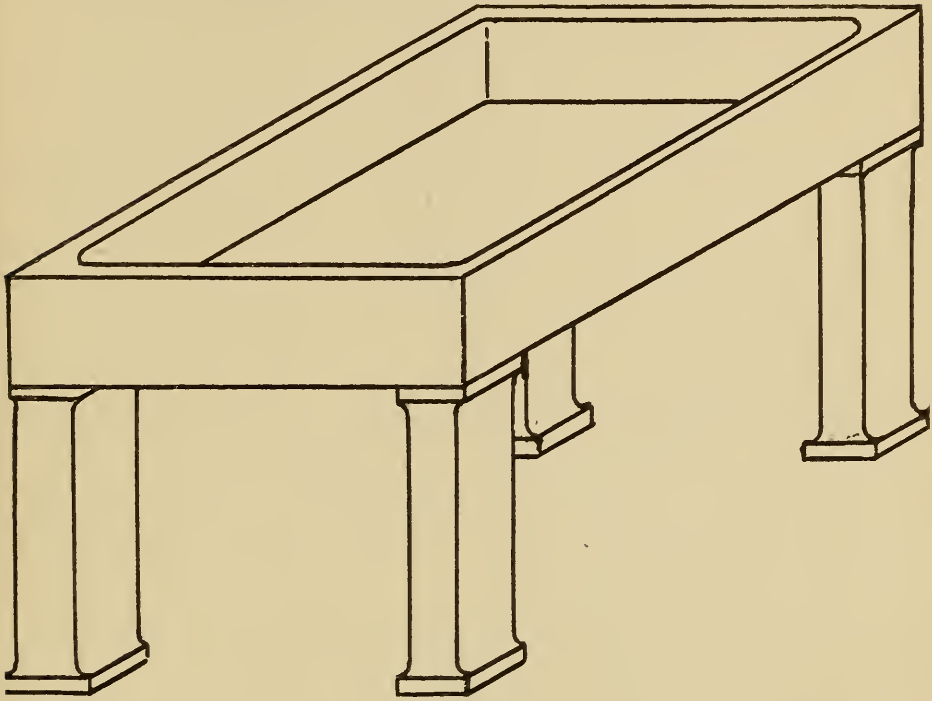


FIG. 114

SHEARING STRESS

In cutting through a bar we cut through its section: then in shearing stress always find the sectional area.

The shearing stress of wrought iron is usually considered to be 52,000 pounds (23 tons) per square inch.

That is, a stress of 52,000 pounds is required to cut through every square inch of sectional area.

EXAMPLE. What shearing stress will cut through a three-quarter inch rivet?

.75 × .75 × .7854 = .44178750 sectional area of rivet. (Fig. 115.)

Then, .44148650 × 52,000 lb. = 22.972 lb. *Ans.*

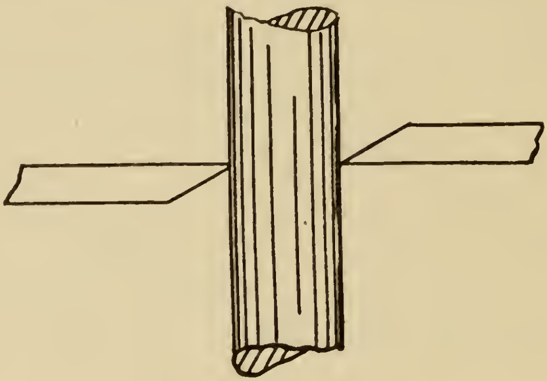


FIG. 115

The foregoing examples will serve to demonstrate the process for determining the magnitude of the strain carried per square inch of section which may be caused by the action of the various stresses.

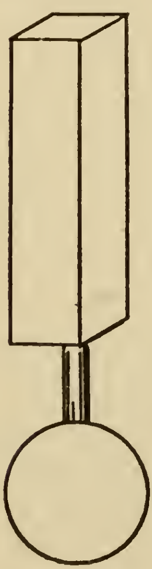


FIG. 116

EXAMPLES DEMONSTRATING THE PROCESS FOR CONSTRUCTING PARTS OF SUFFICIENT STRENGTH TO CARRY LOADS OF KNOWN MAGNITUDES.

EXAMPLE. A square wrought-iron bar is to carry a weight of 208,000 pounds, what must be its sectional area? (Fig. 116.)

Let us employ a factor of safety of 4. That is, we will suppose the load which is to be sustained will be 4 times greater than 208,000, which is 816,000 pounds. As the piece of material in question is subjected to a tensial stress, we find by referring to table No. 1 that the ulti-

mate tensial strength of wrought iron is 52,000 pounds per square inch of section.

Therefore, to find the required area of section, divide the load 816,000 pounds by the ultimate strength 52,000 pounds.

$$\frac{832,000}{52,000} = 16 \text{ square inches. } \textit{Ans.}$$

EXAMPLE. What must be the sectional area of a square cast-iron block which is to sustain a weight of 160,000 pounds. (Fig. 117.)

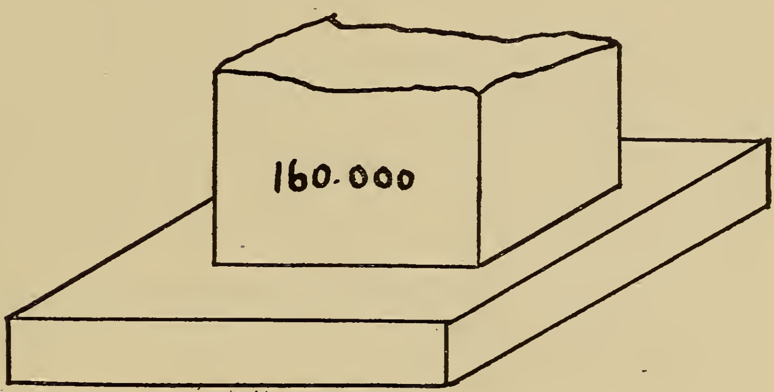


FIG. 117

Let us employ a factor of safety, say 5 for cast iron. That is, we will suppose the load which is to be sustained will be 5 times greater than 160,000, which is 800,000, pounds. As the piece of material in question is subjected to a compressive stress, we find by referring to table No. 1 that the ultimate compressive strength of cast iron is 90,000 pounds per square inch of section.

To find, then, the required area of a section, divide the load, 800,000 pounds by 90,000.

$$\text{Thus } \frac{800,000}{90,000} = 8.888 \text{ square inches. } \textit{Ans.}$$

EXAMPLE. What must be the sectional area of a wrought-iron bolt to withstand a shearing stress of 80,000 pounds? (Fig. 118.)

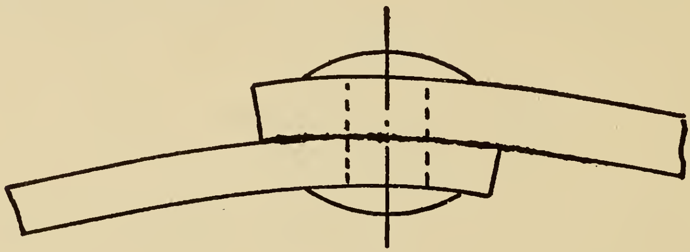


FIG. 118

Let us employ a factor of safety of 4 for wrought iron. That is, we will consider the load which is to be carried to be 4 times greater than 80,000 pounds that is, 320,000 pounds. As the piece of material in question is subjected to a shearing stress, we find, by referring to table No. 1, the ultimate shearing stress of wrought iron to be 52,000 pounds per square inch of section.

To find, then, the area of a section capable of sustaining a shearing stress of 80,000 pounds, divide the load 320,000 by 52,000.

$$\text{Thus, } \frac{320{,}000}{52{,}000} = 6.153 \text{ square inches. } \textit{Ans.}$$

EXAMPLES SHOWING THE PROCESS FOR DETERMINING THE AMOUNT OF STRESS ON BEAMS

EXAMPLE. If a beam 10 feet long fixed at one end has suspended from it a weight of 300 pounds, what is the stress at the point where the beam is fixed? (Fig. 119.)

RULE. The intensity of the force is equal to the force multiplied by the length of the perpendicular to the direction of the force from a point in which the beam is supposed to be fixed.

Therefore, the stress on the beam at A in pounds equals $300 \times 10 = 3000$ lb.

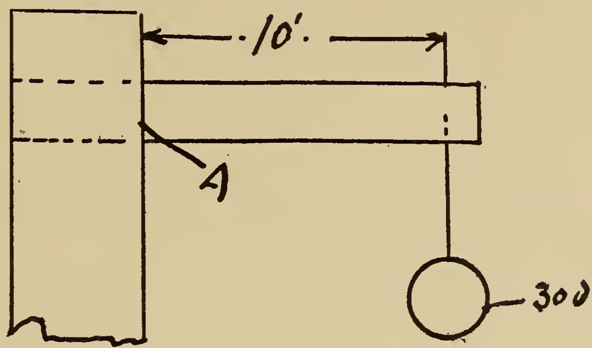


FIG. 119

Because the length of the perpendicular from A, the point at which the beam is fixed to the center of the force 300 equals 10 feet, and $300 \times 10 = 3000$ lb.

EXAMPLE. What is the stress at B, Fig. 120, when a weight of 300 pounds is suspended from the free end of beam?

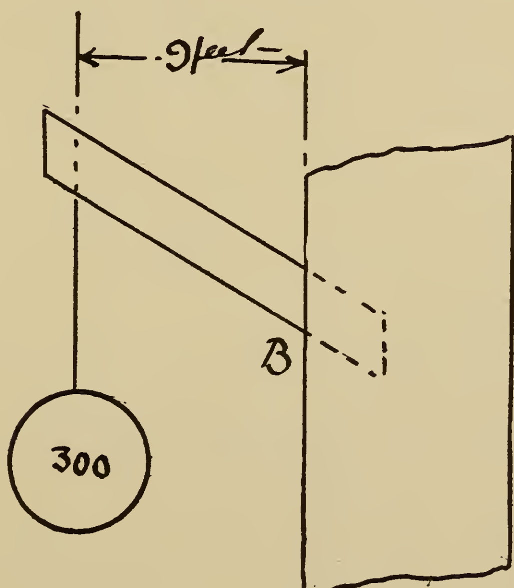


FIG. 120

In this case a perpendicular drawn from the point at which beam is fixed to the center of line of the force is 9 feet, therefore the stress at B = 300 × 9 = 2700 lb.

The stress throughout the length of a beam fixed at one end and loaded at the other is not uniform. That is, the stress varies at different parts of the beam.

The intensity of the stress is greatest at the point where the beam is supposed to be fixed and gradually diminishes in intensity toward the load.

For instance, there is more stress on the beam at A (Fig. 121), than at B, and the stress is greater at B than at C.

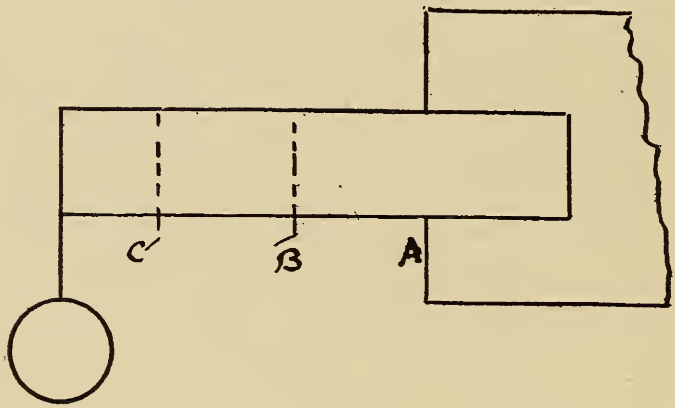


Fig. 121

To Find the Stress in Foot Pounds of any Section of a Beam

Rule. Multiply the load by its distance from the section. For instance, it is required to find the stress at a section 5 feet from the free end of a beam from where a load of 100 pounds is suspended. (Fig. 122.)

Thus 100 × 5 = 500 lb.

That is, the intensity of the stress on the beam at a point (section) five feet from the load, the load being 100 pounds, is 500 pounds.

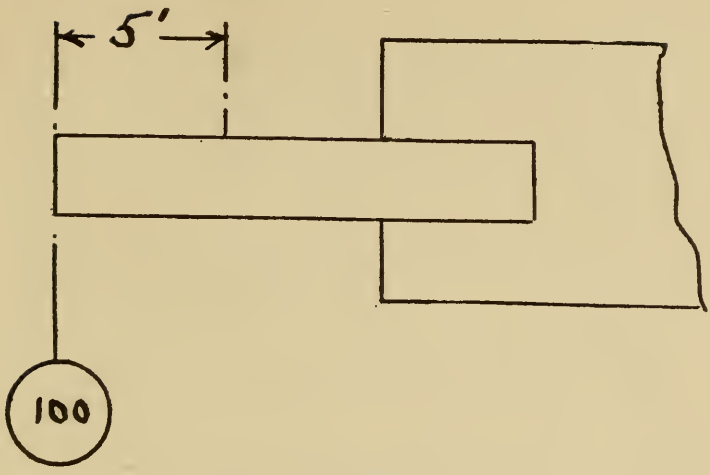


FIG. 122

EXAMPLE. What is the stress on a section of a beam 2 feet from the load, the beam being fixed at one end and carrying a load of 300 pounds?

Thus, $300 \times 2 = 600$ foot pounds.

The above examples fully demonstrate that the greatest stress is at the point where the beam is supposed to be fixed, and that it gradually diminishes toward the load.

Therefore it is customary, when constructing beams of this nature, to make them strongest where the greatest stress comes. (Fig. 123.)

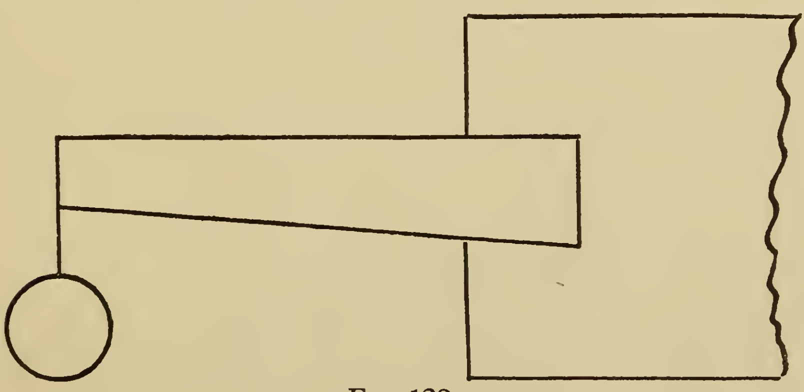


FIG. 123

Example. If the greatest stress allowed on wrought iron be taken at 52,000 lbs. per square inch, what should be the sectional area at the wall A of a wrought-iron beam 66 inches long, supporting a weight of 2 tons suspended from its free end? (Fig. 124.)

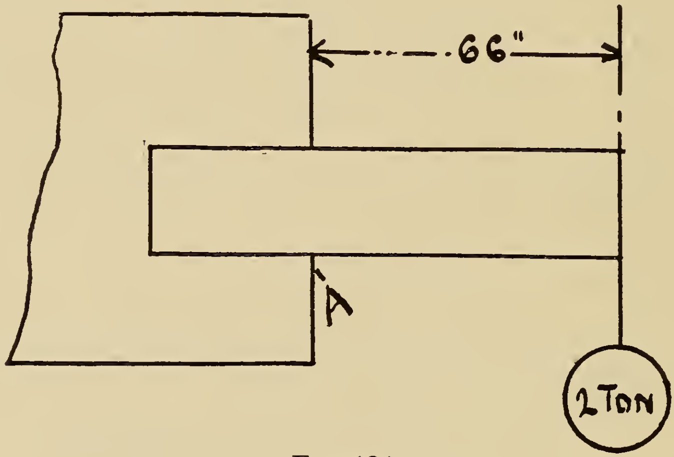


Fig. 124

2 tons = 4000 lb.

4000 × 66 = 264,000 lb. stress at A.

Let us now employ a factor of safety of 4 for wrought iron. That is, consider the stress 264,000 at A to be 4 times greater = 1,056,000 lb.

Then, 1,056,000 ÷ 52,000 = 20.31 square inches. *Ans.*

Example. A beam 56 inches long fixed at one end supports a weight of 5000 pounds. What will be the stress on the beam at fixed end A, and what will be the stress at end B? (Fig. 125.)

5000 lbs. = stress at B.

5000 × 56 = 280,000 lb. stress at A.

Example. A beam is 3 inches thick, 5 inches deep, and 56 inches long. What stress will be put on it per

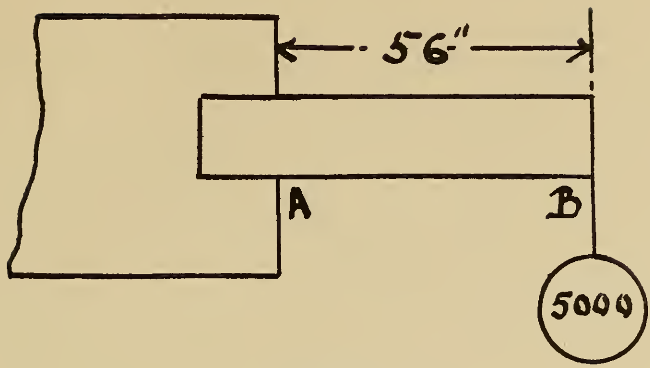


Fig. 125

square inch of its section at B, by hanging a weight of 5000 pounds from its extremity? (Fig. 126.)

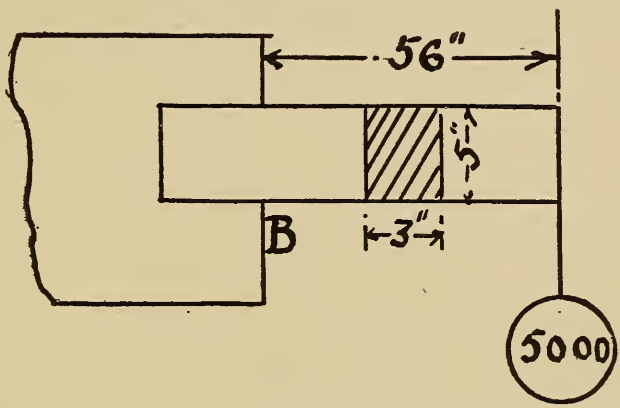


Fig. 126

Thus $3 \times 5 = 15$ square inches of section.
$5000 \times 56 = 280{,}000$ lb. stress at B.
$280{,}000 \div 15 = 12{,}000$ lb. per square inch. *Ans.*

Example. If a wrought-iron beam 66 inches long has to carry weight of 5000 pounds, what ought the sectional area of the beam be at its fixed end, and what ought its sectional area be at its extremity? (Fig. 127.)

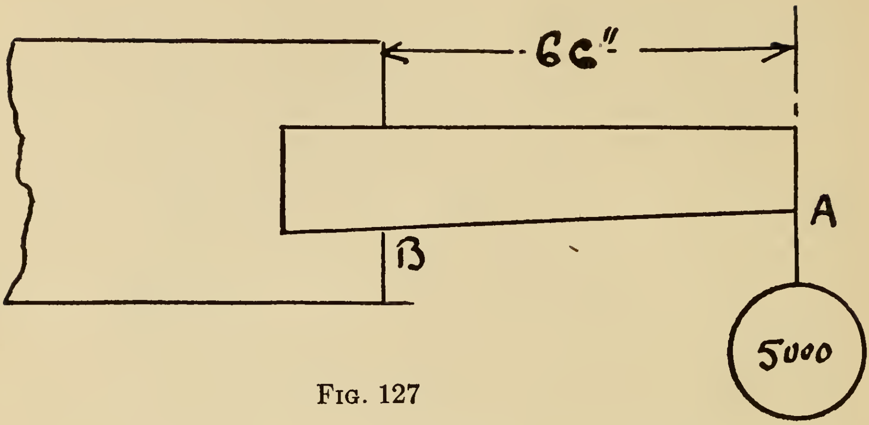


Fig. 127

$5000 \times 66 \times 4 = 1{,}320{,}000$ lb. stress at B.
$5000 \times 4 = 20{,}000$ lb. stress at A.
$1{,}320{,}000 \div 52{,}000 = 25.5$ square inches required at B.
$20{,}000 \div 52{,}000 = .36$ square inches required at A.

ANSWERS

ANSWERS

ANSWERS TO PAGE 8

1. Five.
2. Twenty-five.
3. Three hundred and forty-two.
4. One thousand six hundred and seventy-four.
5. Fifty-four thousand three hundred and forty.
6. Nine hundred and sixty thousand seven hundred and eighty.
7. Three million seven hundred and twenty-six thousand nine hundred and two.
8. Fifteen million nine hundred and eight thousand six hundred and sixty.
9. Three hundred and two million six hundred and seven thousand six hundred and six.
10. Five billion three million three thousand and three.
11. Thirty-two billion six hundred seventy-three million three hundred thousand three hundred.
12. Nine hundred and ninety-nine billion nine hundred and ninety-nine thousand nine hundred and ninety-nine.

ANSWERS TO PAGE 9

1. Four thousand three hundred and sixty-four.
2. One thousand nine hundred and twenty-seven.
3. Nine thousand and nine.
4. Four hundred and thirty-four thousand six hundred and seventy-two.
5. Six million four hundred and ninety-seven thousand nine hundred and twenty-three.
6. Fifty-three million two hundred and ninety thousand six hundred and seventy-eight.
7. Five hundred million four hundred and ninety thousand and sixty-nine.
8. Five billion eight hundred and sixty-seven million three hundred and forty thousand and sixty-eight.

ANSWERS TO PAGE 10

1. 3,725.
2. 12,600
3. 322,006.
4. 6,050,020.
5. 38,420,350.
6. 222,835,130.

ANSWERS TO PAGE 15

1. 100,677.
2. 17,903,922.
3. 2,394,627.
4. 127,228,172.
5. 784,666,605.

1. .26219.
2. .8552072.
3. .40750202.

ANSWERS TO PAGE 63

1. 8477640537.
2. 600238144 $\frac{17}{20}$
3. 205761317 $\frac{13}{28}$.
4. 51549479 $\frac{42}{63}$.
5. 174172502 $\frac{35}{41}$
6. 3082404.
7. 25096125 $\frac{862}{987}$
8. 1080637 $\frac{2101}{2406}$.

ANSWERS TO PAGE 51

1. 804 $\frac{3}{5}$
2. 42066$\frac{1}{4}$.
3. 1649 $\frac{1}{5}$
4. 87235$\frac{1}{3}$.
5. 91734 $\frac{1}{7}$.
6. 113082.
7. 227307 $\frac{5}{9}$.
8. 4081.
9. 110094 $\frac{567}{1200}$.
10. 8422115 $\frac{1}{11}$.
11. 1205456.

ANSWERS TO PAGE 40

1. 548076.
2. 194032332.
3. 2739987852.
4. 12610201200000.
5. 668968011290000.

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